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ENGINEERING:

An Illustrated Weekly Journal.

EDITED BY WILLIAM H. MAW AND ALEX. RICHARDSON.

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See page 17, July 1. 9108

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See Advertisement page 35.

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See Advertisement page 36. 9091

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See Advertisement page 68, July 1. 3499

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See Full Page Advertisement page 72, June 24.

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See Full Page Advt., page 77, June 24.

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GRAPHITED GREASE. 9206
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See Advt. Page 100, July 1.
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B. & S. Massey, Ltd.,
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TENDERS.

LONDON COUNTY COUNCIL.

Tenders are Invited for the

SUPPLY of 2000 TRAILING WHEEL TYRES for Electric Tramcars.
The Form of Tender may be obtained from the GENERAL MANAGER, London County Council Tramways, 23, Belvedere Road, Lambeth, S.E. 1.
No Tenders received at the County Hall, Spring Gardens, S.W., after 12 Noon on Tuesday, 19th July, 1921, will be considered.
The Council does not bind itself to accept the lowest or any Tender.

JAMES BIRD,
Clerk to the London County Council.
R 355

URBAN DISTRICT COUNCIL OF ENFIELD.

STEAM WAGGON AND TRAILER.

The Council invite

Tenders for the Supply and

DELIVERY of a 5-ton STEAM WAGGON and 3-ton TRAILER.
Full particulars can be obtained of Mr. H. R. CRABB, Surveyor, at these Offices.
Tenders to reach me not later than Noon on Tuesday, the 19th July proximo.

T. W. SCOTT,
Clerk.

Public Offices,
Enfield, Middlesex,
30th June, 1921. R 345

THE BURMA RAILWAYS COMPANY, LTD.

The Board of Directors of the Burma Railways Company, Limited, are prepared to receive

Tenders for the Supply of

100 WHEELS without AXLES for Covered Goods Wagons.
For each copy of the Specification a fee of 10s. will be charged, which fee is not returnable. Tenders, enclosed in sealed envelopes, addressed to the "Chairman and Directors" and endorsed "Tender for Wheels without Axles" must be delivered at the Company's Offices not later than 12 noon on Wednesday, 20th July, 1921. The Directors do not bind themselves to accept any or the lowest Tender, and reserve the right to divide the order.

By Order of the Board,
W. HOME,
Managing Director.

120, Gresham House,
Old Broad Street,
London, E.C. 2.
6th July, 1921. R 363

BROWNHILLS URBAN DISTRICT COUNCIL.

BROWNHILLS, STC., STAFFORDSHIRE.

PUMPING MACHINERY.

TO MANUFACTURERS OF OIL ENGINES AND OF STERROPHAGUS CENTRIFUGAL PUMPS.
The Brownhills Urban District Council invite—

Tenders for the Manufacture,

DELIVERY, ERECTION and SETTING TO WORK OF TWO OIL ENGINES AND FOUR STEREOPHAGUS PUMPS (of a combined capacity of 45,000 gallons per hour), also of OTHER MACHINERY; in accordance with the Specification and Drawing prepared by their Consulting Engineer, Mr. ROBERT GRESS, M.Inst.C.E., 37, Waterloo Street, Birmingham, from whom copies can be obtained on and after MONDAY, the 11th July, 1921, upon the payment of Three Guineas, which will be returned only to those Manufacturers who submit a bona-fide Tender not subsequently withdrawn.
These Documents will only be issued to bona-fide Manufacturers of Oil Engines and of Stereophagus Pumps respectively.
Sealed Tenders addressed to the undersigned, to be delivered before Noon on WEDNESDAY, the 3rd August, 1921.
The Council does not bind itself to accept the lowest or any Tender submitted.

By Order,
W. FRED HALL,
Solicitor and Clerk to the Council.
31, Park Street, Walsall,
1st July, 1921. R 289

"INVINCIBLE" MARINE ENGINE and NEW TRAWL WARP.

Tenders Invited for New

"Invincible" Vertical Single-cylinder two-cycle Semi-Diesel OIL ENGINE, 25 B.H.P., 250 R.P.M., 12-in. cylinder, 12½-in. stroke, 28-in. flywheel, approximate weight 50 cwts.
Also for NEW 8½-in. TARRED TRAWL WARP, length about 240 feet, weight about 7 cwt. Both lying at Whitstable. Seen by appointment.—J. T. RHEVES & SON, 44, High Street, Whitstable, Kent. R 392

TO ELECTRICIANS AND OTHERS.

THE METROPOLITAN ASYLUMS BOARD invite

Tenders for carrying out

ALTERATIONS and REPAIRS to the ELECTRIC LIGHTING, FIRE ALARM and DOMESTIC BELL INSTALLATIONS at St. George's Home, Milman's Street, Chelsea, in accordance with Specification prepared by Mr. T. COOPER, M.Inst.C.E., M.I.Mech.E., Engineer-in-Chief. The Specification and Form of Tender may be inspected at the Office of the Board, Embankment, E.C.4., on and after 10 a.m. on Wednesday, 6th July, and the Specification and Form of Tender can then be obtained upon payment of a deposit of £1 in respect of the work. The amount of the deposit will be returned only after the receipt of a *bona fide* tender sent in accordance with the instructions on the form of tender and after the specification has been returned.
Tenders addressed as noted on the form must be delivered at the Office of the Board not later than 2.30 p.m. on Wednesday, 20th July, 1921.

(By Order) DUNCOMBE MANN,
Clerk to the Board. R 354

THIRSK RURAL DISTRICT COUNCIL.

AERIAL ROPEWAY FOR TRANSPORT OF STONE, BOLTBY.

Tenders are Invited for the

COMPLETION of the above WORKS, Total Length 4,400 ft. Difference in level approximately 800 ft. in favour. Capacity 30 tons per day.
The work has been commenced and a quantity of the material is upon the site, several foundations for trestles have been put down.
Application for permission to view the site and materials to be used in the construction, should be made to the undersigned.
Tenders and Specifications for the completion of the Ropeway, including the provision of the material required to complete, should be submitted on or before the 8th day of August, 1921, to

WILLIAM SWARBRECK,
Clerk to the Council.

Council Offices,
Finkle Street, Thirsk,
4th July, 1921. R 360

BOMBAY, BARODA AND CENTRAL INDIA RAILWAY COMPANY.

The Directors are prepared to receive up to Noon on Wednesday, the 27th July

Tenders for the Supply of—

CLASS A.
1. COPPER FIREBOX PLATES.
2. STEEL BOILER TUBES, FLUE TUBES AND STEAM PIPES.
3. LAMINATED BEARING SPRINGS.
4. WHEELS AND AXLES.

CLASS B.
1. CAST STEEL WHEEL CENTRES FOR LOCOMOTIVES.
2. AXLES FOR LOCOMOTIVES.
3. TYRES FOR LOCOMOTIVES.
4. AXLE BOXES FOR WAGONS.
5. BRASS BOILER TUBES.

Tenders must be made on forms, copies of which, with specification, can be obtained at these offices on payment as follows:—
For Class A, 30s. each and for Class B, 10s. each (which will not be returned).
The Directors do not bind themselves to accept the lowest or any tender.

S. G. S. YOUNG,
Secretary.

Offices:
The White Mansion,
91, Petty France,
Westminster, S.W. 1.
4th July, 1921. R 353

THE GREAT INDIAN PENINSULA RAILWAY COMPANY.

The Directors are prepared to receive

Tenders for the Supply of the

following STORES, namely:

No.		Fee for Specification.
1.	Steel Work for Bridges (Ollivant Road Overbridge)	£1
2.	Spare parts of Carriages and Wagons (Axleguards, etc.) ...	10s.
3.	Dressed Wagon Covers	£1
4.	Galvanised Stamped Steel Mortar Pans	5s.
5.	Mauntles for Lamps	5s.

Specifications and Forms of Tender may be obtained at this office on payment of the fee for the Specification, which payment will not be returned.
The fee should accompany any application by post. Cheques and Postal Orders should be crossed and made payable to the Great Indian Peninsula Railway Company.
Tenders must be delivered in separate envelopes, sealed and addressed to the undersigned, marked "Tender for Steelwork for Bridges," or, as the case may be, not later than Eleven o'clock a.m., on Tuesday, the 19th July, 1921.
The Directors do not bind themselves to accept the lowest or any Tender.

R. H. WALPOLE,
Company's Offices, Secretary.
48, Copthall Avenue, E.C. 2.
London, 6th July, 1921. R 356

APPOINTMENTS OPEN.

BIRMINGHAM MUNICIPAL TECHNICAL SCHOOL.

Wanted Mechanical Engineer

(age 25 to 35), to take charge of heating, ventilating and electric lighting plant, including Babcock boiler, gas engines, and electric generators.—For full particulars, apply SECRETARY, Municipal Technical School, Suffolk Street, Birmingham. R 376

THE UNIVERSITY OF LIVERPOOL. FACULTY OF ENGINEERING.

Applications are Invited for

the MUNITIONS COMMITTEE FELLOWSHIP.—Value £250—preference being given to graduates in Engineering of the University of Liverpool.
Applications should be addressed to the REGISTRAR, the University of Liverpool, and be received by him not later than Friday, July 15th, 1921, from whom further particulars may be obtained. R 367

UNIVERSITY OF GLASGOW.

CHAIR OF NAVAL ARCHITECTURE, including MARINE ENGINEERING.

The University Court will,

about the beginning of next session, PROCEED to FILL the VACANCY in the Chair of Naval Architecture, including Marine Engineering, caused by the retirement of Professor Sir JOHN H. BILES.
Information regarding the Chair may be obtained on application to the SECRETARY of the University Court, The University, Glasgow.
June, 1921. R 278

COUNTY BOROUGH OF EAST HAM EDUCATION COMMITTEE.

EAST HAM TECHNICAL COLLEGE: EVENING CLASSES.

PRINCIPAL:—W. H. BARKER, B.Sc., F.C.S.

Required, Teachers for:—

(A) Mechanics and Heat, on Tuesday and Friday Evenings from 7 to 9.30 o'clock.
(B) Manual Training Metalwork for the City and Guilds of London Institute Examinations, on Thursday and Friday Evenings from 7 to 9.30 o'clock.

Preference will be given to candidates who have had experience in teaching. A form of application, together with the conditions of appointment and scale of salaries, may be obtained from the undersigned or from the PRINCIPAL, Technical College, East Ham, E. 6.

(Signed) F. R. THOMPSON,
Secretary.

Education Office,
Town Hall, East Ham, E. 6.
27th June, 1921. R 341

LANCASTER EDUCATION COMMITTEE.

STOREY INSTITUTE TECHNICAL AND JUNIOR TECHNICAL SCHOOL.

Wanted for September

next:—
(A) ASSISTANT MASTER to teach principally Science subjects.
(B) ASSISTANT MASTER to teach principally Practical Drawing and Metalwork.

Salaries, whether Graduate or Non-Graduate, provisionally according to the Burnham Scale for Teachers in Secondary Schools pending the issue of the Burnham Scale for Teachers in Technical Schools.
Forms of application and particulars should be applied for at once from the undersigned.

GEO. H. MITCHELL,
Secretary for Education.

Town Hall, Lancaster,
4th July, 1921. R 365

Estimator (Cost) Required by

firm Engineers and Boilermakers in London. Only men with drawing office and previous estimating experience need apply. State full particulars and salary required.—Address, R 314, Offices of ENGINEERING.

Junior Technical Assistant

(Temporary) Elasticity Research. An Hons. Degree in Physics or Mechanical Engineering. Age not over 30. Commencing salary £300/350 inclusive. Applications marked "Elasticity" will be considered only from ex-service men and should be sent to The SECRETARY, JOINT SUBSTITUTION BOARD, Montagu House, Whitehall, S.W.1, not later than the 14th July, giving full statement of qualifications and experience. Only those candidates whose qualifications appear prima facie suitable will be interviewed. R 361

Two Junior Technical Assistants

(Temporary) for general or analytical work (ferrous and non-ferrous) in a Metallurgical Department of the Government Service. An Hons. Degree in Engineering or Metallurgy and some experience in a Works laboratory. Commencing salary £300/350 inclusive. Applications marked "Metallurgy" will be considered only from ex-service men and should be sent to the SECRETARY, JOINT SUBSTITUTION BOARD, Montagu House, Whitehall, S.W.1., not later than the 14th July, giving full statement of qualifications and experience. Only those candidates whose qualifications appear prima facie suitable will be interviewed. R 360

SOUTH STAFFORDSHIRE WATERWORKS COMPANY.

CIVIL ENGINEERING ASSISTANT.

The above Company require at once the

Services of a Civil Engineering Assistant,

about 30 years of age, with technical and practical training and conversant with the work of large Waterworks Undertakings. Preference will be given to Applicants who are good draughtsmen, with experience of Parliamentary work, and who have had actual experience of Main Laying, Reservoir Construction, Sinking of large Boreholes, are competent Surveyors and Levellers. Applicants should be Associate Members of the Institution of Civil Engineers.
Applications giving age, details of experience, and salary required, and enclosing copies of recent testimonials must be addressed to the undersigned:

FRED. J. DIXON, M.Inst.C.E.,
Engineer-in-Chief.

30a, Paradise Street, Birmingham. R 358

THE CITY AND GUILDS (ENGINEERING) COLLEGE.

ELECTRICAL ENGINEERING DEPARTMENT.

The Delegacy are prepared to receive

Applications for a Post as

DEMONSTRATOR in ELECTRICAL ENGINEERING. Salary commencing at £300.
Applications, stating age, and giving full particulars of education, training and experience, should be addressed in the first instance, to Professor T. MATHER, F.R.S., City and Guilds (Engineering) College, South Kensington, S.W. 7, before 22nd July, 1921. R 338

Wanted, for Indian Galvanizing Works, an ENGINEER (unmarried)

as Assistant Manager, with practical experience in the manufacture of Galvanized Tanks, Buckets, Hollowware and Light and Heavy Galvanized work generally.—Write stating age, experience, and salary required, to E.Y. 881, care of DEACONS, Leadenhall Street, E.C. 3. R 339

Engineer Wanted, Midland

area, to take charge of moderate size works producing high-class speciality (not mass production). Good technical qualifications and engineering experience. Age about 30-35. Salary £400 per annum with prospects.—Address, R 356, Offices of ENGINEERING.

Young Structural Engineer

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Candidates, under 40, must be qualified Civil Engineers and have had experience in the working of rotary, preferably shot drills, and be competent to take full charge of drilling operations. A knowledge of geology is desirable although not essential, but the person selected must be competent to keep records of geological strata passed through, to arrange cores in boxes in the correct sequence and to prepare sections showing the exact point at which each stratum is met and passed through.
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Engineer (32), Mechanical and

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OPTICAL ROTATORY DISPERSION.

ALTHOUGH the engineer makes use of polarised light in the exploration of stress-strain problems, he may leave that study to the specialist, and the distinction between optical rotatory power and rotatory dispersion need not trouble him much. We do not observe the one without the other, and there was until quite recently little co-ordination between general optical properties and the considerable amount of experimental material on optical rotation that has accumulated within the century. The ground has become clearer during the last decade. The old belief that optical rotation and chemical constitution must closely be interrelated has been strengthened, and since at present the constitution of the atom and molecule and radiation are the fundamental problems, to which almost every research is traced back, a review of the position of "Optical Rotatory Dispersion," as given by Dr. T. M. Lowry, of Cambridge, and Dr. P. C. Austin in their Bakerian lecture before the Royal Society on June 2, will be of interest.

Optical rotatory power and dispersion go together; the discovery of the rotatory dispersion may, in fact, be said to have preceded that of rotatory power. When Arago in 1811 interposed a quartz plate between his polariser and analyser, set to extinction, he observed a sequence of beautiful colours. Biot showed a year later that these colours were due to a rotation of the plane of polarisation, the rotation increasing both with the thickness of the plate and with the change of colour from red to violet; thus dispersion came in. It proved impossible to extinguish all the colours simultaneously with any setting of the analyser, while in the absence of the quartz plate complete darkness could have been produced, and Biot's early measurements of optical rotatory power indeed included observations of rotatory dispersion. Biot first assumed that the rotation of the plane of polarisation or the optical rotatory power α was inversely proportional to the square of the wave-lengths λ and could be expressed by $\alpha = k/\lambda^2$. Whether the discrepancies of a few per cent. which he noticed were due to experimental errors or to an inaccuracy of his formula, he was unable to decide. As the observations multiplied, however, stronger deviations from the inverse square law were brought out. At the same time the experiments were simplified in a rather unfortunate manner.

The D line of sodium in the Bunsen flame supplied (since 1866) so convenient a source of light that the experimenters were satisfied with obtaining by the aid of monochromatic light a single point on a curve of unknown form. That Dr. Lowry rightly characterised as a retrograde step. Biot had made use of the monochromatic light of his days, a ruby glass, but he had also studied the effect of light of different wave-lengths. The several improved formulæ proposed under these conditions did not really advance matters, until Drude, at the close of the past century, applied the electronic theory to optics. His formula showed how the "dispersion constant" λ^2_0 could be deduced from the refractive power of the medium, and he gave a similar formula for the magnetic rotatory power of Faraday. That the optical and the magnetic rotatory power were proportional to one another in crystals, had been shown by G. Wiedemann; but Lowry and Desch later found that this proportionality did not hold for optically-active liquids. Drude tested his formula only for quartz, carbon disulphide and creosote. He was unable to pursue the matter experimentally—overwork drove him to suicide in 1906. His formulæ, moreover, involved an indefinite number of arbitrary constants and required a complete knowledge of the refractive dispersion which was not then available. But a great deal of valuable work has been done since that time, both on the Continent and in this country, over here notably by Dr. Lowry and his collaborators.

From 50 series of measurements of optical and magnetic rotatory dispersion made on groups of organic compounds, Drs. Lowry, T. W. Dickson and R. H. Pickard, found that all the readings could be expressed by using a single term of Drude's equation involving only the "rotation constant k" and the dispersion constant λ_0^2, the λ_0 referring to an ultraviolet radiation. The formula was $\alpha = k/(\lambda^2 - \lambda_0^2)$. This law of simple rotatory dispersion was found to hold for most alcohols, acids, sugars, terpenes, &c. But it failed in the case of metallic tartrates in aqueous or alcoholic solutions, for instance, and this "complex dispersion" varied in a peculiar way, attaining a maximum in the green and then decreasing towards the violet.

The last-named solutions, moreover, proved extraordinarily sensitive to changes in concentration and temperature, as Biot had already noticed. Further, the curves of substances such as tartaric acid itself and its esters were shown by Dr. Austin to be anomalous in three respects, as to inflection, maximum and reversal of sign; these anomalies appearing at various points of the experimental curves as the concentration varied. Yet the wide range of the anomalies was covered by a two-term Drude formula $\alpha = k_1/(\lambda^2 - \lambda_1^2) - k_2/(\lambda^2 - \lambda_2^2)$. Only when the second of these terms is negative the dispersion is "anomalous"; when both are positive, it is "complex in the sense of Lowry" and Austin.

Quartz is an example of the complex type. To study quartz, Dr. Lowry made use of a column of lævo-quartz (turning the plane of polarisation to the left), 500·8 mm. in length, in the form of nine rods, cut from a single crystal and put into optical contact with one another. Photographing an iron arc through these 20 in. of quartz with the aid of a polarimeter and a spectroscope Dr. Lowry obtained rotations for 700 different wave-lengths ranging from 11,920 deg. for $\lambda = 5{,}383{\cdot}360$ A.U. to 84,763 deg. for $\lambda = 2{,}327$ A.U. and to 101,332 deg. for the copper line 2,263 A.U. (leaving out some of the decimals which are essential, however), that is to say, the plane of polarisation was turned by the long column through hundreds of complete circles of 360 deg. each. These measurements accorded again within 1 deg. with Drude's formula, which thus received its most complete demonstration. The first positive term predominates so strongly over the second negative term throughout the spectrum that anomalous dispersion is suppressed. We should add that in Dr. Lowry's first measurements of 1912 the agreement was not so satisfactory, because the wave-lengths of the iron lines used were not very accurately known.

What now is the cause of the difference between (I) simple and (II) complex, or (III) anomalous rotatory dispersion? Mathematically we have one type of formula which reduces to one term in case I, to two positive terms in case II, and to one positive and one negative term in case III. Chemically one feels tempted to ascribe the complexity of optically-active molecules to the presence of two liquids, each characterised by simple rotatory dispersion corresponding to one of the terms which differ as to sign and dispersive power. The suggestion is not new. Biot produced already in 1836 an artificial anomaly, when he attempted to neutralise the optical rotatory power of lævo-turpentine by dextro-oil of lemon, and Arndtsen put the case quite clearly for tartaric acid which he regarded as a mixture of two substances differing only as to positive and negative rotatory power. That was in 1858, long before isomerism was understood in the extended modern sense. At present chemists speak, for instance, of enantiomorphs, substances which have in the molecule the same number of atoms grouped, in exactly the same way (not in different ways, as in ordinary isomers), but which differ as to right and left, as much as the two gloves of a pair or an object and its mirror image. There is, further, dynamic isomerism also studied by Lowry. Some bodies split into isomers as soon as they are dissolved, the isomers differing slightly with respect to the grouping of the atoms, though we are rarely able to separate the two isomers. That change is accompanied by a "muta-rotation," *i.e.*, a change of rotatory power in the freshly-prepared solution. Nitrocamphor is such a substance; the change can be observed, but in the presence of a trace of piperidine the change is so rapid that it can no longer be detected.

In tartaric acid and its esters now the interconversion may be equally rapid since careful observation have failed to detect any lag of rotatory power after dissolution, dilution, distillation or fusion. It may be thought that there is little new in this. It has long been understood, of course, that tartaric acid itself and its derivatives exist in a dextro-series and a lævo-series, the one turning the plane of polarisation to the right, the other to the left. But the point is that Dr. Lowry and Austin only worked with dextro-tartaric acid and its derivatives, not touching the *l*-series. They found that this *d*-acid itself shows anomalous or complex rotation acting like an isodynamic mixture of two substances. Examining the curves of rotatory dispersion over a wide range, from the red lithium lines to the violet mercury lines, they proved each curve to be the means of two simple hyperbolæ on opposite sides of the horizontal axis of wave-lengths, but running to different vertical asymptotes. Thus, by preparing two series of derivatives from the apparently homogeneous free acid, so far inseparable into components, they established that the *d*-acid really consists of two substances differing as to sign, rotation and the dispersive power. Simple salts of the acid had been believed to possess simple rotatory dispersion. Dr. Lowry and Austin showed them to have complex dispersion, though the second term of the equation is very small and vanishes altogether in the boro-tartaric acid. The new models of molecules will have to account for this additional complication; but complications sometimes indicate the way to the solution of a problem.

RECENT MACHINE TOOL DEVELOPMENTS.—No. XX.

By JOSEPH HORNER.

THE present article deals with the horizontal boring, drilling, and milling machine built by Messrs. Cunliffe and Croom, Limited, of Manchester. It is constructed in three sizes, with spindles of 2⅝ in., 3 in. and 3½ in. diameter, respectively, the one illustrated being the medium size. As is now usual, the motions are all derived from a single belt pulley, running at a constant speed (190 r.p.m.), for which a direct motor drive can be substituted. The photograph, Fig. 385, page 34, and the two external views, elevation and plan, Figs. 386 and 387, indicate the general outlines, with which the subsequent details can be compared.

The geared speed-box is shown by Figs. 388 to 390, page 35. The 15-in. pulley A, making 190 r.p.m., drives the lower shaft in the box at constant speed for speeds and feeds. From the combinations of gears, eight spindle speeds are derived, these being in revolutions per minute: 116, 65, 40, 22½, 16, 9, 5½ and 3. The pulley shaft, Fig. 388, has a spur gear B keyed on it, driving to C, keyed on a sleeve that encircles the upper shaft, so driving the sleeve continuously. The sleeve is prolonged to the right to carry a spur gear D, which meshes permanently with a larger gear E on the lower shaft, the sleeve extension of which to the right carries a ring clutch F, expanded with a slider, that puts the spur G into action. The sleeve above, which carries the gears C and D, is extended to the right to receive a slider with its expanding ring clutch H, that puts the spur gear J into action, this being loosely running, and always meshing with the wheel G on the lower shaft. The other side of gear J is fitted with a ring clutch K, slider-operated, the clutch being keyed to a sleeve which carries the spur L, meshing permanently with M on a sleeve on the feed shaft below, M also having its clutch N, put in with a slider. The sliders are actuated by double-ended forked levers, seen in Fig. 388, and shown separately in Fig. 391, pivoted at the centre, and moved with the levers outside the box, Fig. 390, with the result that when an upper clutch is put in, the lower one is thrown out, and *vice versa*, rendering it impossible for conflicting speeds to be engaged at the same time. The pinion O, in one with the sleeve that carries the gear M, is always in mesh with the wheel P on the upper shaft, whence, through the mitres Q the eight speeds obtained by the combinations in the box are transferred to the boring head. P runs loosely, being put into action by the sliding jaw clutch R, when moved to the right by its forked lever, shown separately in Fig. 392. When moved

to the left, the drive goes through L, M, O, P. The detail of the clutch is shown in Figs. 393, 394. It is expanded by the coned ends of the sliders pressing against the abutment pins, which are case-hardened. The operating levers are seen at S, T, U, Figs. 386, 389, U being the starting lever which puts in the clutch R in Fig. 388. A speed and feed chart, annexed to Fig. 386, shows the positions of the levers for the different speeds, which if compared with Fig. 388 will enable the several combinations to be traced. No sliding of gears is done. The box is a detached unit, bolted down through its lugs to the bed of the machine. It has a hinged cover at the top for inspection. The shafts are drilled up for the lubrication of the sleeves.

Connections from the gear-box are shown in Figs. 395 to 398, on Plate V. These go to the vertical shaft V through which the spindle speeds are transmitted, and to the feed gears for the boring bar, the spindle head, and the work-table, the various transmission shafts for which are shown.

The spindle drive commences with the mitre Q on the upper shaft in the speed-box, Fig. 388, seen again in Fig. 395. Here it is seen engaging with mitres on a vertical shaft V, either of which is rendered operative with a sliding jaw clutch, feather-keyed to the shaft, moved by a bell-crank lever W, Fig. 386, and Fig. 396, which gives a side view of the box in Fig. 395. The upper and lower mitres rotate the transmission shaft V in one direction or the other, with resulting reversal of the spindle rotation, compare with Fig. 386. The shaft V is received in bushes in the gears, and the bosses of the latter are extended to run in bushes in the bosses of the gear-box. The vertical movement of the shaft is prevented by a washer below and a lock-nut above. The relation of the box containing these gears to the end of the speed-box at the left is clear, It is bolted to the facings at the right hand end of the latter, one of the hold-down lugs of which is seen in Fig. 395.

Feed transmission from the lower shaft in the gear-box, Fig. 388, starts from the spur gear X, Fig. 395, whence, through an intermediate in Fig. 397, necessary to raise the centre, the spur gear Y, seen in the part plan view, of the box, Fig. 398, meshes. The transmission goes from the shaft on which Y is keyed to a mitre Z, keyed on the other end of the shaft. Two sliding mitres carried on a clutching sleeve mesh with this in turn for reversing the quick power feed, according to the direction of movement of the bent lever A A. The sleeve on which the sliding mitres are feather-keyed is extended towards the front of the box,—compare with the sectional view in the upper part of Fig. 398—to form a claw clutch to transmit and reverse the motion of the vertical feed shaft B B—compare with Fig. 386—the motion going through the bevel gears of 12 and 60 teeth. The spindle saddle feed is transmitted through the 35 and 50-toothed bevels at the bottom of the shaft C C. This can be hand-operated from the front of the box with a wrench on the squared end at D D., Fig. 386. The sleeve that carries the sliding jaw clutch, Fig. 398, is extended to receive a 16-toothed bevel keyed to the sleeve, and running loosely on a bush, meshing with one of 24 teeth, that of 16 teeth being rendered operative by the claw clutch and lever E E. The splined shaft F F that carries the larger bevel transmits the table movements and feeds. The box that contains these gears is cast in one with the machine bed. In these views, Fig. 395 is a part face view, Fig. 398 combines a longitudinal vertical section above, extending from the front of the box to within the column, and a part plan view below. The box comprises a rectangular body, and a circular portion in front seen clearly in the photograph. The speed transmission within the saddle, and the feed changes affected there may now be traced.

The speed changes from the gear-box on the bed, Fig. 388, pass up through the 2-in. vertical shaft V, Fig. 386, through the mitres Q, of 25 teeth to the horizontal shaft G G, Figs. 399, 400 and 401, on Plate V, which carries a pinion of 26 teeth meshing with a wheel of 72 teeth on the spindle, shown in Fig. 403. The changes of eight speeds are received therefore directly from the gear box, with reversal as stated, by the cranked lever W, Figs. 386 and 396.

HORIZONTAL BORING AND DRILLING MACHINE.

CONSTRUCTED BY MESSRS. CUNLIFFE AND CROOM, LIMITED, ENGINEERS, MANCHESTER.

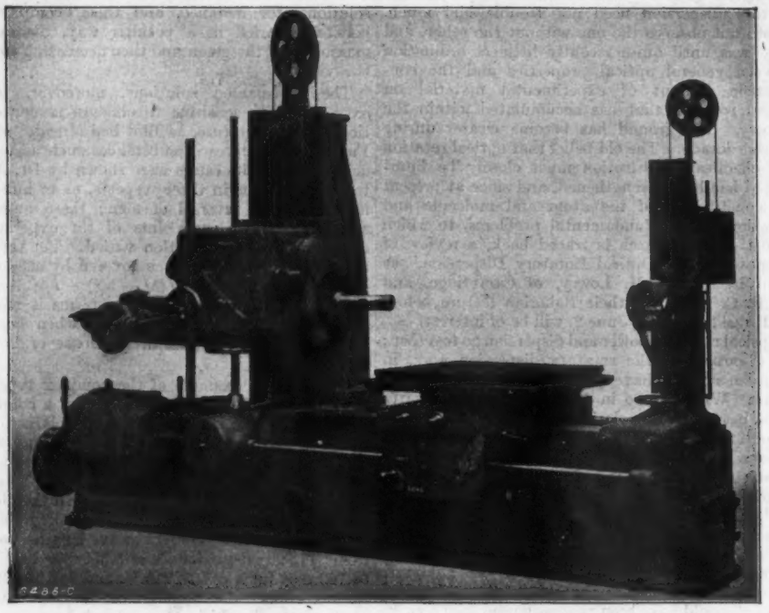


FIG. 385.

SPINDLE SPEEDS, R.P.M.				FEEDS, CUTS PER INCH						
LEVER POSITIONS	SPEEDS	LEVER POSITIONS	SPEEDS	FEED CHANGE LEVER	FEED BACK GEAR	POSITION OF FEED BOBBIN	SPINDLE HORIZ.	SPINDLE VERT.	TABLE LONG.	TABLE TRANS.
S T U	116		16	A	OUT	D	10	8	16	20
	65		9			C	20	16	32	40
	40		5¼	B	IN	D	48	38	80	100
	22¼		3			C	94	75	157	196

Fig. 386.

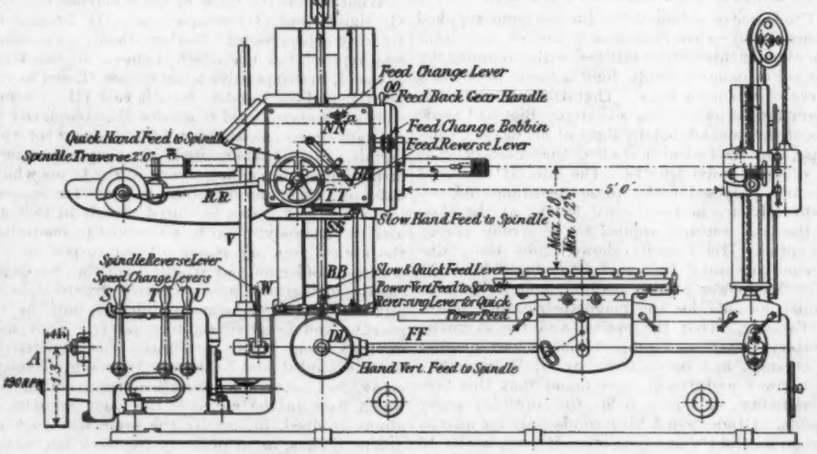
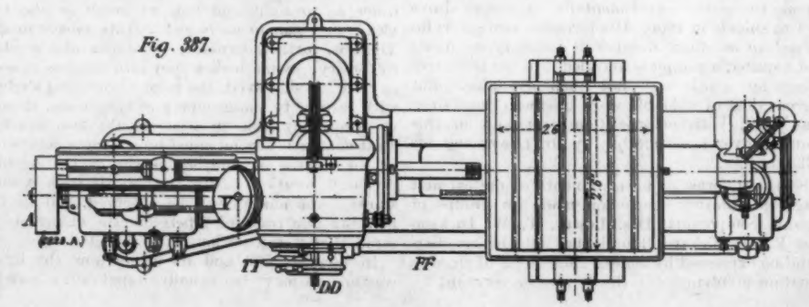
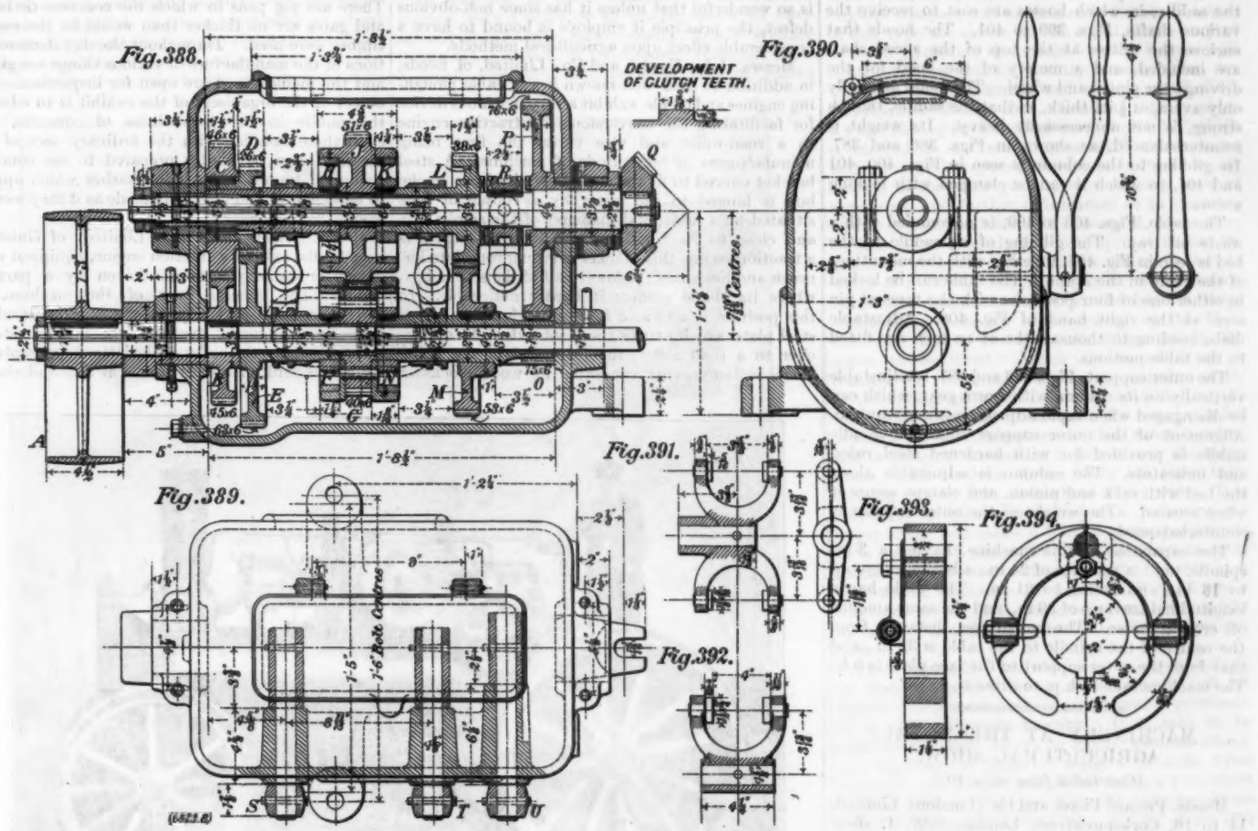


Fig. 387.



SPEED-BOX OF HORIZONTAL BORING AND DRILLING MACHINE.

CONSTRUCTED BY MESSRS. CUNLIFFE AND CROOM, LIMITED, ENGINEERS, MANCHESTER.



The feed changes are as follows: The 1¼-in. shaft B B, coming up from the feed-box in Fig. 398, is connected to the feed changes with mitres of 33 teeth, Fig. 399, with a central reversing clutch operated by the lever H H, driving a mitre on a horizontal shaft. The locking of the lever in its three positions is indicated in Fig. 399, and it, with its clutch slider is shown in detail in Fig. 402. The horizontal shaft carries two spurs J J and K K, loosely running and put into operation by means of the dive key, and sliding bobbin that actuates it, and through which the spurs L L and M M, respectively, Fig. 400, running loosely together on a bush on the pinion shaft, mesh. M M is one of the back gear train, put in with the claw clutch that is feather-keyed on the pinion shaft when moved to the right with the lever N N to the position *a* in Fig. 386. For the back gear drive which doubles the two feed changes obtained by the pairs of pinions just mentioned, an eccentric shaft, Fig. 400, carries gears of 40 teeth, and 16 teeth on a sleeve, that mesh with 25 teeth and 50 teeth (M M) respectively, running on bushes on the pinion spindle, and put in and out with the lever O O, Figs. 394 and 399.

The feeds are derived from the pinion shaft that drives the spindle, since the double-ended clutch, spline-keyed to it puts the change-feed gears into action. When the lever N N is moved to the right, the gears L L and M M are in operation, when to the left, the first back gears of 26 and 40 teeth are clutched. The feeds then passing through J J or K K, put in with the dive key, Fig. 399, are transmitted to the nest of 33 toothed mitres, clutched with the feed reverse lever H H. Either being brought into mesh with the clutch, transmits the changes in feed rate, and determines the direction of rotation of the shaft, and with it the direction of feed of the boring spindle.

The feed to the spindle goes through a worm keyed on the vertical shaft, driving a worm wheel P P, of 70 teeth, Figs. 399 to 401, thence through mitres Q Q, of 21 teeth, to the diagonal shaft R R, and to bevels of 13 and 52 teeth at its opposite end, Fig. 404, to the rack pinion of 15 teeth, Figs. 403 to 405. The worm and its wheel can be turned for making hand adjustments with the hand wheel S S below the gear-box, which, by turning the worm directly imparts a slow hand feed to the spindle. The quick hand feed is imparted with the hand wheel T T in front of the box. The worm wheel runs loosely on its shaft, being driven with a cone clutch pushed in with the large hand wheel T T, and locked with the small hand wheel that is screwed on the outer end of the clutch shaft.

The connection between the feed-box in Fig. 399, and the vertical feed of the column saddle is through the lug U U, at the back of the saddle in Figs. 400 and 401, screwed to 1¾ in. The connection to the table feed is through the shaft F F, in Fig. 398. The four feeds to each of these movements are transmitted down their vertical shafts, from the spindle head, and put in with their claw clutches.

The splined shaft F F, going to the work-table, Fig. 406, extends along the front of the bed, Figs. 386, 387 and goes through a bearing attached to the saddle, rotating with a sleeve, keyed to move along the spline. The sleeve is solid with a 16-toothed bevel pinion, engaging with one of 40 teeth, keyed on a sleeve free to pivot on a bush on the wheel shaft—compare with Fig. 408—and having cut on it an 18-toothed spur pinion W, from which connection is made through an idler of 34 teeth to another 18-toothed pinion W W above. A lever is rocked on the axis of the idler to bring the upper pinion W W into mesh with one of 22 teeth X X—compare Figs. 406 and 407—for longitudinal traverse of the table, which goes through a worm and its wheel of 20 teeth on a vertical spindle, driving the 12-toothed pinion Y Y, Fig. 409, engaging the rack below the saddle, Fig. 408. For the transverse feed of the table, the motion goes through the pinion W to another Z Z, of 18 teeth, Fig. 406, on the end of the screw which engages with a nut, Fig. 409, on the bottom of the table support.

These admirably-schemed drives, and feeds all actuated from the one pulley, and controlled with levers and hand wheels located closely together, with a chart of speeds and feeds, corresponding with the various positions of the levers, afford a remarkable contrast with the tedious belted movements, and gear dispositions in use until recently. We may now note some of the constructional features which are illustrated in these drawings.

The spindle is seen in Fig. 403, Plate V. It slides on the main driving sleeve, within which it is fitted by grinding. The sleeve runs in coned bearings of gun-metal, with provision for adjustment by means of lock nuts at the rear. The front cone terminates in a steep angle, the spindle neck being enlarged to suit, so that there is no liability to seize. It is driven by the 72-toothed gear at the front, the face of which is provided with tee-slots to form a face plate for the mounting of large milling cutters, or facing heads. The wheel with its pinion, Fig. 400, is enclosed with a cast-iron hood, the front portion of which is removable. The thrust of the spindle is taken in both directions against Hoffman ball bearings, located at the rear end, which also have means for adjustment. A felt washer is fitted between the spindle and sleeve.

The cross-section of the extension of the spindle cradle to the left is shown in the detail, Fig. 405. It is hollow, of D-shape, and is stiffened with flanking ribs above. The weight of overhang is lessened by the longitudinally-tapered outline. The sliding bearing that carries the rear end of the spindle is coerced with gib strips on each side—compare with Fig. 401. The feed rack which it carries is attached with sunk cheese-head screws in a shallow recess in the bottom of the bearing.

This fitting and the long extension at front and back ends ensure steadiness of sliding movements. The saddle casting, Figs. 403 and 404, is a neat bit of design and of moulder's work. It is nearly all cored, not only the D-section, but the interior of the saddle, in which bosses are cast to receive the various shafts, Figs. 399 to 401. The hoods that enclose the mitres at the top of the speed shaft are included, and a moiety of the hood for the driving spur pinion and wheel. The metal generally only averages ¼ in. thick, so that the saddle, though strong, is not unnecessarily heavy. Its weight is counterbalanced, as shown in Figs. 386 and 387. Its gibbing to the column is seen in Figs. 400, 401 and 404, to which it can be clamped with locking screws.

The table, Figs. 406 to 409, is surrounded with a waste oil tray. The gibbing of its saddle to the bed is seen in Fig. 408, together with the mountings of the gears in the apron. The table can be locked in either one of four positions with the tapered pin seen at the right hand of Fig. 406. Adjustable dials, reading to thousandths of an inch are fitted to the table motions.

The outer support, Figs. 386 and 387, is adjustable vertically on its column with worm gear, which can be disengaged when rapid adjustments are required. Alignment of the outer support with the spindle saddle is provided for with hardened steel rules, and indicators. The column is adjustable along the bed with rack and pinion, and clamps secure it when located. The weight of the outer support is counterbalanced.

The capacities of this machine, having a 3-in. spindle, are: a traverse of 24 in., a boring range up to 18 in., and facing to 21 in. The table has a longitudinal traverse of 30 in., and the same amount of cross-traverse. The maximum distance from the centre of the spindle to the table is 32 in., and that from the outer support to the face plate is 5 ft. The machine takes 8 h.p. to drive it.

MACHINERY AT THE ROYAL AGRICULTURAL SHOW.

(*Concluded from page* 10.)

Messrs. Piccard Pictet and Co. (London), Limited, 14 to 16, Cockspur-street, London, S.W. 1, show soil tilling machinery which is well worth inspection, as it effects cultivation in a manner entirely different from the usual sequence of operations. The "Simar," as the machine is called, is of Swiss origin. It is a small machine consisting of a two-cylinder Vee engine, developing 7 b.h.p. at 1,200 r.p.m., and mounted on a carriage which it propels by means of a pair of tractor wheels. The rear end of the carriage is supported by a single small swivelling wheel. Immediately in front of the latter is a transverse shaft carrying a number of hooked tines mounted on springs, so that they are flexible in every direction. As the machine goes along, the shaft revolves at about 200 r.p.m., and the tines scratch away the earth and leave a completely finished seed bed behind. The show ground, which was composed of thoroughly hard old grass land, was reduced to a fine tilth, equal to that which would have required ploughing, cultivating and harrowing to produce in the ordinary way. The machine has forward speeds of 1¼ m.p.h. and 2½ m.p.h., and normally tills a width of 28 in. This can be reduced to 22 in., which is the overall width of the wheels, by removing the outer tines, so that the machine can work along narrow alleys between rows of trees, &c. The depth of tillage may be varied at will from 3 in. to 10 in., and the machine will cultivate from 1 acre to 3½ acres per day according to conditions. It uses ½ gallon of petrol per hour and weighs 5 cwt. in working order. For heavier work, the special tilling device is fitted behind and driven from a tractor of more or less standard design. The "Simar" tractor so equipped has a four-cylinder engine developing 25 b.h.p. at 1,000 revs. The "miller" can be lifted by the driver from his seat, and can be easily disconnected altogether when the tractor is required for other purposes, or can be replaced by a reaping or other attachment. This machine tills a track 4 ft. 3 in. wide, to a depth regulatable between 2 in. and 12 in. It will till from 3 to 14 acres per day of 10 hours, according to depth, &c., and consumes from 5 gallons of petrol per day in light soil, up to a maximum of 30 gallons per day of 10 hours, when tilling 12 in. deep in the heaviest ground. The simplicity of the machine is so great, and the work it will do "from the solid," is so wonderful that unless it has some non-obvious defect, the principle it employs is bound to have a considerable effect upon agricultural methods.

Messrs. John Fowler and Co., Limited, of Leeds, in addition to their well-known heavy cable ploughing engines and tackle, exhibit a very ingenious device for facilitating the conversion of a traction engine to a road-roller and vice versa, the firm being manufacturers of both kinds of machine. A steel bracket curved to fit the outer surface of the smoke box is hinged to the latter by a couple of pins situated on a horizontal diameter of the smoke box and close to its front end. When the engine is a traction engine this bracket is swung round underneath and lies along the lower half of the smoke box, where its shape renders it hardly noticeable. In this position it acts as a foundation for the pressed steel plate which carries the front axle. To change over to a road roller, the front end of the boiler barrel is temporarily supported by wood blocks or other packing from the ground, the front axle removed and the bracket swung round on the pins through 180 deg., so that it projects horizontally in front, forming practically a continuation of the top of the smoke box, to which it is then bolted by semi-circular flanges which come together in that position. It then looks very much like the ordinary bracket at the front of a road-roller, and the front rollers with their yoke and swivel are attached to it in the usual way. The driving wheels of the traction engine are then changed for roller wheels, and the transformation is complete. This device should save much time and prove of great convenience to road authorities and others to whom an easily convertible engine is a useful piece of equipment.

The Concrete Utilities Bureau, of 35, Great St. Helens, London, E.C.3., show a very remarkable collection of concrete work, which indicates in a striking manner how much this material is coming into use, even for purposes for which one would think it could never complete commercially with timber or steel. The display includes full-sized concrete signal posts, lent by the Great Northern and Midland Railways. These are hollow with cored openings. The platform on the post, and the brackets which support it are all of concrete. The general appearance is excellent, and the durability of the structure is, of course, indefinite. Another striking feature of the display are the post and rail fences, which except for colour and feel are indistinguishable from timber, as the exact proportions and style have been retained. As a contrast to them a portion of the ordinary post and rail fence is shown, in which the posts are rotted away at the ground. The various kinds of articles made of concrete are altogether too numerous to mention, but what strikes one particularly is the thinness and the excellence of finish of much of the material. There are pig pens in which the concrete divisions and gates are no thicker than would be the case if timber were used. Throughout the day demonstrations of the manufacture of various things are given, and the moulds used are open for inspection. The object of the organisers of the exhibit is to educate the public in the possibilities of concrete, and even those familiar with the ordinary uses of the material may be hardly prepared to see concrete cucumber frames and window sashes which appear to be as lightly and delicately made as if they were of wood.

Messrs. Walsh and Clark, Limited, of Guiseley, near Leeds, exhibit a traction engine, equipped with drum for cable ploughing, driven by a paraffin engine. The general lines of the machine, as will be seen from the photograph reproduced in Fig. 7, subjoined, resemble those of a steam traction engine, the boiler of the latter being replaced by an oil tank of almost identical size and shape,

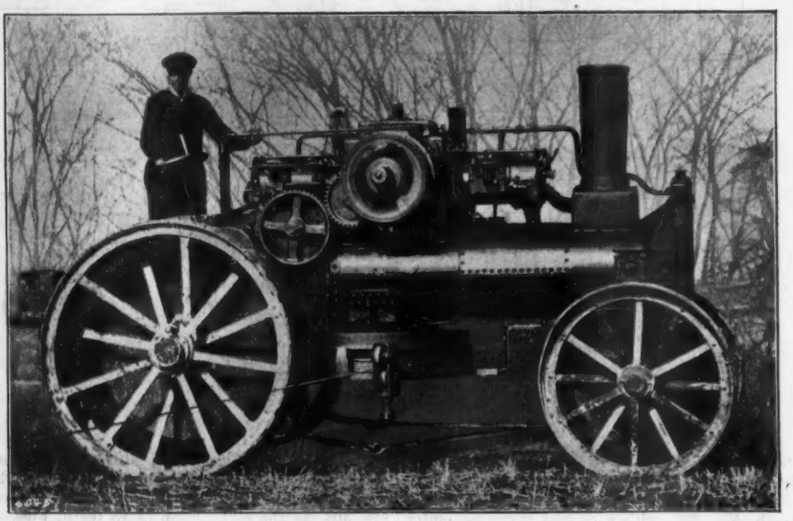


FIG. 7. OIL-DRIVEN CABLE PLOUGHING ENGINE; MESSRS. WALSH AND CLARK, LIMITED, GUISELEY.

capable of holding 50 gallons of fuel, which is sufficient for more than four days' ploughing. The engine has two opposed horizontal cylinders, 7 in. diameter by 8 in. stroke, each driving its own crank-pin. It develops a maximum of 45 b.h.p. at 500 r.p.m. Petrol is used for starting, but as soon as the engine is warm, it runs on paraffin which is vaporised by the heat of the exhaust in the usual way. The complete machine weighs about 5½ tons, and has two speeds for road travelling, namely, 2¼ m.p.h. and 4½ m.p.h. It will haul an 8-ton load on the level at the latter speed. The cable drum, which is placed in the same position as on steam ploughing engines, carries 450 yards of ½-in. steel rope. Rope speeds of 250 ft. to 350 ft. per minute are obtainable, and a continuous pull of 4,500 lb. on the rope can be maintained by the engine. A pair of these engines will plough from 7 acres to 10 acres per day of 10 hours, according to the nature of the work, or will cultivate twice this amount. A four-furrow plough is used on light land, and a three-furrow plough on heavy land. The engine can, of course, be equally well used for stationary work, such as the driving of threshing machines, &c.

Messrs. Frank Slacey and Co., Limited, Vauxhall street, Birmingham, show a complete plant for bleaching flour by the Alsop electrical process. As there is a popular belief that the whiter flour is, the better it is, various processes have been devised to whiten it. In the Alsop process air which has been drawn past a low tension electric arc is used as a bleaching agent. The action of the arc

is to produce a certain amount of nitrogen peroxide in the air, and this gives it its bleaching property. The apparatus consists of a double-acting air pump, so arranged that the air approaching the automatic inlet valves is drawn down through narrow cylindrical chambers containing wrought-iron electrodes. Current is supplied to these electrodes at about 440 volts from a small dynamo, the current passing through a very large inductance in circuit. At the proper moment the electrodes are brought into contact and immediately separated, with the result that a flaring arc several inches long is drawn out between them. The pump with the electrode chambers and working mechanism is mounted on a cast-iron frame, and is a nice-looking piece of apparatus. The arcs can be seen through transparent windows, normally covered by slides. The pump delivers the treated air to a receiver at 1½ lb. per square inch pressure, whence it is piped to the agitators. These are horizontal machines, something like screw conveyors, the screw being formed of a series of independent blades mounted on a revolving shaft. These blades mix up the flour with the air, and finally work it along to the delivery end of the machine. The complete plant absorbs very little power, about 1·5 h.p. being sufficient to treat 100 sacks of flour per day. The process is said to be easily controllable to give the flour any required degree of whiteness, and the flour is stated to be sterilised by the treatment. What happens to the vitamines we do not know.

In addition to the "Glasgow" three-wheeled tractor, with a drive on all wheels, which we have already illustrated in these columns, Messrs. Wallace (Glasgow), Limited, of Dennistown, Glasgow, show a small vertical totally-enclosed paraffin engine which has several interesting features of design. Its inlet and exhaust are controlled by a sleeve valve which oscillates both horizontally and vertically at the same time, the motion being obtained from a crank driven by the half-speed shaft. This shaft runs in substantial bearings and carries a pulley, giving an alternative low-speed drive. The exterior of the cylinder has continuous vertical cooling fins. These are covered by sheet metal casing which extends partly over the top of the cylinder and causes the cooling air first to impinge on the top of the cylinder head and then to travel vertically down the outside of the cylinder. The lower side of this casing forms a large eye, leading the air to the centre of the flywheel, which is really a modified single-inlet multivane fan impeller of cast-iron. Thus a vigorous air circuit is always maintained by the action of the flywheel. It is claimed that the engine has 70 per cent. fewer parts than a corresponding engine of the usual type. The cylinder head is detachable and the combustion space entirely symmetrical. The whole design is original, compact and mechanically sound. Engines of this type are shown on the stand direct-coupled to small dynamos, the whole forming very simple electric lighting sets for country houses, farms, &c.

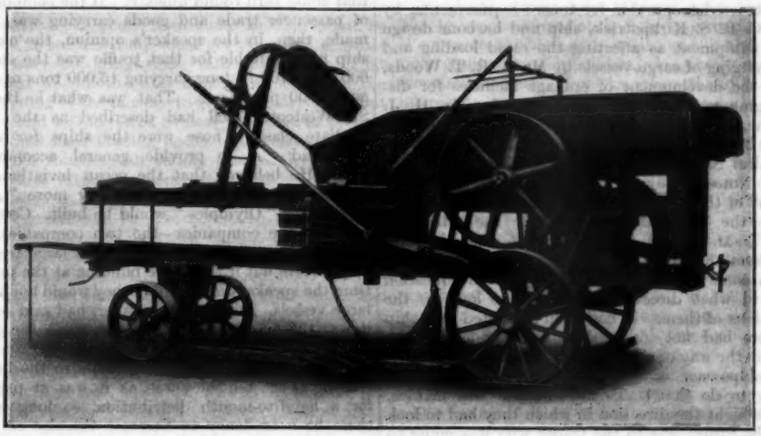


FIG. 8. 20-TON BALING PRESS FOR HAY AND STRAW; MESSRS. RUSTON AND HORNSBY, LIMITED, LINCOLN.

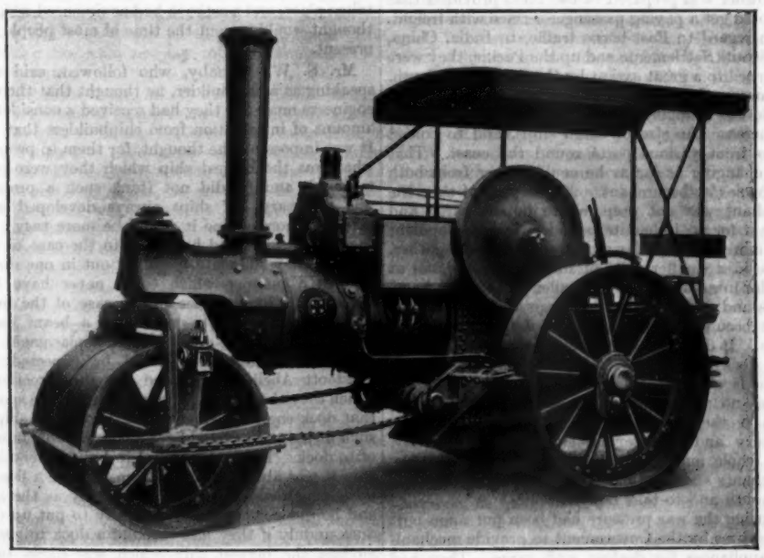


FIG. 9. COMPOUND STEAM ROAD ROLLER; MESSRS. RUSTON AND HORNSBY, LIMITED, LINCOLN.

Messrs. Siebe Gorman and Co., Limited, 187, Westminster Bridge-road, London, S.E. 1, show a water-raising device called the "Aquatole," which is entered as a "new implement," although we noticed it at last year's show. It is, however, as erected in the show yard, a very striking piece of apparatus, and further information as to its capabilities is now available. It consists of one or more endless belts formed of helical springs linked together by pins, the length of the springs being the width of the belt. The belt hangs vertically from a horizontal drum, the bight at the bottom being steadied by a heavy roller resting in it. It is otherwise free. The roller is submerged in the water to be lifted. When the upper drum is rotated the rising side of the belt entrains water in the springs of which it is composed, and as the belt moves upwards faster than the water can fall downwards, the consequence is that water is raised and is flung off the belt as it passes over the upper drum. The machine at the Show has three belts running side by side, each about 12 in. wide. It is driven by an oil engine belted to a pulley on the upper shaft, and raises 5 tons of water per minute to a height of about 20 ft. The effect is most spectacular, the water descending in torrents in a glass-walled enclosure. Several small hand-power machines are on view, these being suitable for lifts up to 40 ft., and deliveries up to 500 gallons per hour.

The "Aqualole" has obviously no pipes, valves, or other mechanism to go wrong, and it will lift liquids of any consistency or any degree of grittiness. It is also eminently portable. It is said to be applicable to any lift up to 500 ft. without alteration of design or type. A chain 1 in. wide, hand operated, will lift 500 gallons per hour, a 2 in. chain will lift 1,800 gallons per hour for an expenditure of 0·025 b.h.p. per foot of lift. A 6 in. chain lifts 6,000 gallons per hour for 0·076 b.h.p. per foot and a 12 in. chain lifts 22,000 gallons per hour for 0·210 b.h.p. per foot of lift. Chains of intermediate widths are also standardised.

A great feature of the Show this year is the number of manufacturers of motor road transport vehicles who are exhibiting. Motor lorries, omnibuses, charabancs are shown by many firms, but in general these vehicles follow along fairly standard lines, and do not call for much comment. Messrs. Tilling-Stevens Motors, Limited, of Maidstone, Kent, shew several petrol-electric chassis, a design which has had considerable success among motor omnibus companies and other users. The Associated Equipment Company, Limited, of Walthamstow, London, E.17, who are well-known as motor omnibus builders, shew a single-deck 36-seat vehicle of this type, and a "charabanc-de-luxe" to seat 28 persons, and listed at £2,250. Leyland Motors, Limited, of Leyland, Lancs., show many heavy vehicles for the transportation of persons and goods, and the stand also contains a handsome motor fire-engine. Dennis Brothers, Limited, of Guildford, also show a 60 h.p. motor fire-engine among their other vehicles, these two firms having laid themselves out for this special class of apparatus when the horse-drawn steam fire-engine became obsolete. Messrs. Straker Squire, Limited, of Angel-road, Edmonton, London, N.18; The Vulcan Motor and Engineering Company, Limited, of Crossens, Southport, Lancs.; Guy Motors, Limited, Fallings Park, Wolverhampton; Commercial Cars, Limited, Luton, Bedfordshire; Halleys Industrial Motors, Limited; and other well-known firms are also shewing petrol-driven road vehicles of various types.

There is little to be said about the traction and portable engines at the Show, because the types have become so thoroughly standardised. Messrs. Marshall, Sons and Co., Limited, of Gainsborough, shew a portable engine, for which the firm claim

a mechanical efficiency of 94·5 per cent., and a fuel consumption of 2·05 lbs. of "combustible" per brake horse-power hour. The engine, which has a single cylinder, 7½ in. diameter by 12 in. stroke, works with saturated steam at a pressure of 150 lbs. per sq. in., and in general appearance follows the usual lines. The same firm have a 5 ton to 6 ton universal tipping wagon mounted on springs. The under-frame carries a turn-table upon which the body, together with the tipping gear, can be rotated, so as to enable tipping to be effected either fore or aft, or on either side at will. Messrs. Ruston-Hornsby, Limited, of Grantham and Lincoln, shew a very fine collection of machinery, as also do Messrs. Clayton and Shuttleworth, Limited, of Lincoln, both firms having traction engines, road-rollers, threshing machines, oil engines, &c., on view.

Among other exhibits Messrs. Ruston and Hornsby, Limited, of Lincoln, show the baling press, and the compound steam road roller illustrated respectively in Figs. 8 and 9 on page 37. The former machine will bale from 15 tons to 20 tons of hay or straw per day. The straw to be baled falls from the threshing machine into an inclined hopper and is automatically conveyed towards the baling chamber by means of a number of vertical feed rakes, protruding through the bottom of the hopper and actuated by gearing. As the ram recedes, the feeder arm, which is connected to it by links, descends into the mouth of the baling chamber carrying with it a charge of straw. On the forward movement of the ram, the arm is withdrawn and the charge compressed. The road roller, shown in Fig. 9, is of the firm's standard type, which is too well-known to need detailed description. These machines with compound engines are built in five sizes, weighing from 8 tons to 16 tons without coal and water, and rolling a track varying in width from 5 ft. 9 in. to 7 ft. 3 in. All but the smallest size are also built with single cylinder engines.

The oil engines at the Show must run into many hundreds altogether. Messrs. Blackstone and Co., Limited, of Stamford, alone have 19 on their stand, ranging from 5½ b.h.p. to 50 b.h.p. Messrs. Petters, Limited, and Vickers-Petters, Limited, have no less than 39 of them, from the Petter-Junior 2½ h.p. type to a semi-Diesel crude oil engine of 50 b.h.p. Crossley Brothers, Limited, of Openshaw, Manchester, The National Gas Engine Company, Limited, of Ashton-under-Lyne, and indeed dozens of other firms show this class of engine, either by itself or arranged to drive a dynamo, pump, or what not. Messrs. Peter Brotherhood, Limited, of Peterborough, have a 22 h.p. crude oil engine amongst their other exhibits which include a 5 ton steam wagon, a two stage air compressor to deliver at 200 lbs. per sq. in., a "Peterboro" agricultural tractor, and a 26½ kw. lighting plant driven by a totally enclosed forced lubricator steam engine.

Messrs. Robey and Co., Limited, of Lincoln, show their 5 ton steam wagon which we illustrated in ENGINEERING, of July 16, 1920, page 66. This, it will be remembered, has a firebox entirely without stays, either on the top or at the sides, thus facilitating cleaning and avoiding much potential trouble. A model of the Uniflow engine is also exhibited. Messrs. J. and H. McLaren, Limited, show steam and motor cable ploughing tackle, and a five-furrow anti-balance plough of attractive design. Messrs. William Foster and Co., Limited, Lincoln, show a traction engine, a steam tractor and a 5 ton steam wagon with rubber tyred wheels and end-tipping body. Messrs. Barford and Perkins, Limited, of Peterborough, show six motor road-rollers from 35 cwt. to 14 tons in weight, in addition to numerous rollers for tennis courts, cricket fields, &c. The excellent display of wire ropes for ploughing, logging, mining and other purposes by Messrs. Geo. Cradock and Co., Limited, of Wakefield, should not pass unnoticed, although we have been compelled to omit mention of many firms whose exhibits, though numerous and impressive, were not of particular novelty.

IRON ORE IN JOHORE.—It is reported officially from Johore that an iron mine has been opened in the district of Batu Pahat, and 5,000 tons of ore are being turned out a month. The ore is shipped to Japan; but there are signs of coal in the same district, and there are hopes that the ore may be smelted eventually on the spot.

THE INSTITUTION OF CIVIL ENGINEERS. ENGINEERING CONFERENCE.

(*Continued from page 24.*)

SECTIONS II AND V.—HARBOURS, DOCKS, RIVERS AND CANALS, AND SHIP-BUILDING.

SHIPS DIMENSIONS AND HARBOUR AND DOCK FACILITIES.

THE joint discussion by Section II and V of three notes on the dimensions to which docks should be constructed to provide for future requirements, by Mr. C. R. S. Kirkpatrick, ship and harbour design and equipment as affecting the rapid loading and discharging of cargo vessels by Mr. A. R. T. Woods, and the development of cranage facilities for discharging vessels of the largest size by Mr. H. J. Deane, was continued on the afternoon of Wednesday, June 29th, under the chairmanship of Engineer Vice-Admiral Sir Henry J. Oram, K.C.B. We printed these Notes on page 31 of our last issue and gave a report of the morning's discussion on page 21.

At the resumed discussion in the afternoon, Mr. T. M. Newell, who spoke first, said that the speakers they had heard that morning had given them some interesting problems, but the question was in what direction they were to look for the solutions of them. It had been suggested that ship owners had not given the dock engineers much lead in the way of size of ships of the future. Was it the shipowner or the ship constructor who was going to do that? To his mind, it was neither. He thought the direction in which they had to look for the future was to the trader who was going to utilise the merchant service; and with regard to the passenger leviathans, to those passengers who were prepared to pay such a sum as would make it worth while for the shipowner to build such ships. The shipbuilder was prepared to turn out any size or class of ships required, and the shipowner was prepared to use them provided that he could get a paying passenger service with freight. With regard to East-borne traffic, to India, China, the Straits Settlements and up the Pacific, they were governed to a great extent by the Suez Canal depth. Of course, they had the Cape route, but even that traffic was changing. The general process had been to increase the size of cargo ships, and to collect cargo from various ports round the coast. That was changing as far as he could gather from both shipowner and merchant. At the present time the merchant was not prepared to import cargo and store it for an indefinite period. The development was more likely, so far as the speaker could gather, to be in a smaller class of ship that would sail at regular intervals from the smaller ports to the home ports and so distribute the cargo and not store it. That brought up the question of facilities at the ports. It did not matter, the speaker said, whether the dock authorities provided cranes or other methods of improving the discharging of ships as it was no use discharging a 5,000-ton ship in two days if the merchant was not prepared to take delivery and remove the goods from the quay. The whole matter was therefore governed by the merchants and the tendency was to live from hand to mouth and to take daily supplies.

During the war pressure had been put upon port authorities by the Government to provide mechanical appliances for dealing with cargo. They had experimented with numerous appliances at Liverpool, but had had trouble with the men, who insisted on the employment of the same number of men when cranes, transporters, or other appliances were provided, as when the cargo was put over the side by the ship's own derricks and winches. No authority could afford to provide electric or hydraulic appliances for doing the work if it were going to cost the same per ton, by the employment of unnecessary labour, to hand over the cargo to the merchant. That was where they were tied up with appliances. They had the greatest difficulty in getting the men to use them. They had tried all sorts in Liverpool, but the use made of them in many cases was nothing like what it ought to be.

The size of ships, the speaker continued, would depend upon the demand. The construction now going on at Liverpool was capable of taking in anything afloat. The new dock construction would lock in a 1,000-ft. ship, but as far as he could gather, it was not coming. The authorities could not afford to provide dock accommodation for ships of that class in London, Liverpool, or any other port, as it was not a paying proposition. If such ships were to be maintained for special passenger traffic, they must be accommodated, not in docks, but at wharves, or landing stages in the river, so as to turn round quickly. The ship that was the best paying proposition to the dock authority was the cargo ship of from 5,000 tons to 8,000 tons, that could turn round quickly. If the combination of passenger trade and goods carrying was to be made, then, in the speaker's opinion, the class of ship most suitable for that traffic was the ship of 600 ft. or 700 ft. long carrying 15,000 tons of cargo and 2,000 passengers. That was what he thought Sir Westcott Abell had described as the intermediate class. Those were the ships for which they had got to provide general accommodation. He believed that the ocean leviathan had seen its day, and doubted if any more "Aquitanias," or "Olympics" would be built. Certainly some of the companies—the two companies who owned those two ships—had bought large German ships of late but if they were building at the present time the speaker did not think they would build such large vessels. As he, the speaker, had said before, it was the man who was going to bring the goods and distribute them to whom they must look to find out what was going to be done in the future. As long as the tendency was, as it was at present, for a hand-to-mouth distribution, so long would there be a tendency to decrease the size of ships instead of increasing them, and if they had to re-design the accommodation at Liverpool to-day, he did not think they would provide for such large ships. The present dimensions were decided upon when the Aquitania was on the stocks. Other accommodation was proposed of similar size, and even for classes larger; but a change had undoubtedly taken place, and a setback had commenced which he thought would see out the time of most people then present.

Mr. S. W. Barnaby, who followed, said that, speaking as a shipbuilder, he thought that the dock engineers must feel they had received a considerable amount of information from shipbuilders that day. It was impossible, he thought, for them to prophesy what was the biggest ship which they were going to build, and he did not think such a prophesy was necessary. If ships always developed along a regular normal line it would be more easy; but they knew what had happened in the case of warships. They suddenly branched out in one dimension in a manner which could never have been foreseen, as for instance in the case of the bulge. The battleship with a bulge had a beam corresponding to a very much larger displacement and draught of water than could be expected. Sir Westcott Abell had pointed out the direction in which they should look, and it seemed to the speaker that dock engineers should provide only for ships of such a size as they could get a considerable number of to dock. If people wanted to build a very large ship it was always open to them to have a floating dock which could be built as quickly as the ship, and he did not think it would pay to put up dock dues unduly if they had to build a dock to accommodate the biggest ship which was likely to be built.

The next speaker, Mr. C. H. Sandeman, said he would like to make a few remarks on Mr. Kirkpatrick's paper, as it appeared to the speaker that the question really was, whether the shipbuilder or the harbour engineer was going to lead the way with regard to the future size of ships. It had been suggested that harbour engineers should look ahead and make provision for larger ships than the shipbuilder could foresee, and that if the harbour engineer led the way, larger ships would come. That opened up a very difficult question for the harbour engineer at the present time. Most of them knew that many extensive schemes were approved before the war and were actually commenced, and no doubt many of them would have been completed now but for the war. The war, however, had completely changed the situation, and harbour engineers had to face the fact that, with depleted

revenue and enormously curtailed expenditure, all those schemes had been relegated to the background. It must be remembered that the question of deepening waterways was dependent, in many cases, upon private works, the cost of which was still very excessive. It had been suggested by one or two speakers that the solution might be found in the provision of floating docks, but he was not in agreement with that view for the reason that, while the floating dock would take a ship, the ship had to get to the dock. He did not think it was suggested that the dock should be moored out in the open sea, but apart from some such proposal he failed to see how they could get the depth of water necessary to bring ships into the docks. That seemed to him to be as difficult as would be the deepening of the fairway to get at the dry-dock, but he would be interested to hear the views of persons who had used floating docks. He trusted that he was not sounding an unduly pessimistic note with regard to future developments; but it seemed to him that if docks were constructed and if works were undertaken to give access to docks at the present time, the increased capital cost was very unlikely to give any return for many years to come.

Sir John Purser Griffith, who continued the discussion, said that one or two points in connection with the size of docks had struck him as matters of very considerable importance. He agreed with the previous speaker, that there was little likelihood of any great dock developments within the next few years. The few words he wished to say on the subject were with regard to finance. A good many dock Boards with which he had been connected had tended to go in for very long loans. It had been the practice in some cases which he had come across to get loans extended to sixty or seventy years, and he thought that that had been the basis of a good deal of the present-day embarrassment. If they had formed sinking funds to repay the loans in twenty-five or thirty years, they would have been in a position to face the number of rapid extensions which had been forced on them by the mercantile marine; he could not lay too great emphasis on that point.

The next speaker, Mr. F. Palmer, C.I.E., said he had not intended to intervene in the debate because he thought it better for men who came from a distance to give them their views, but he thought the remarks of Mr. Freeman, one of the American representatives, should be answered in some way. The question was raised by Mr. Woods on the Thames Barrage—a scheme which the speaker said had been killed many times already. Mr. Freeman, however, spoke of the Charles River Dam, and that was the bugbear that was brought up on every occasion when a barrage was talked about in a navigable river. It came up quite recently in connection with the proposed barrage across the Clyde at Glasgow, and as he was consulted about it he had had occasion to look into the matter. He wished to tell the meeting that the Charles River was a little brook like the Ravensbourne or the Wandle, or the Lee or the Kennet, with a catchment area of 200 sq. miles; it would probably be possible to jump across it in many places. It certainly was navigable for some little distance; but they did not want to put a dam across this stream for the purposes of commerce, because the commerce and trade of Boston was below the dock, not above it. The chief reason for the construction of the dam was the sanitary improvement of the region. It was really comparable with the weirs at Twickenham or Richmond, which had given them another 3 miles or 4 miles of the Thames as a playground.

With regard to the dam and barrage question generally, he would like to say that in his researches in connection with the Clyde Navigation scheme in 1750, Smeaton suggested that there should be a dam across the Clyde, and his proposal, which the speaker had seen, was to make that dam in order to keep the water in the Clyde at the level of high water spring tides, and afford a depth of 4 ft. 6 in. at Glasgow. The ships he had in view were shown by the size of the lock he proposed, which was 70 ft. long and about 20 ft. wide. The speaker wished the meeting to consider that the dam had been built, and to imagine what a disaster it would have been for Glasgow. He was sure that all the engineers who followed Smeaton—Telford, the first president of that Institution, and James Walker, another president—all ignored or condemned the scheme of Smeaton. The fact that Glasgow had to regard as fortunate was that the limitation of shipping entering the Clyde was governed by the river only and not by a lock 70 ft. long. In conclusion, the speaker thought his remarks should correct any wrong impression in the minds of his audience as to the nature of the Charles River Dam.

Mr. L. H. Savile, who followed, said he would like to emphasise what had been stated by Mr. Wentworth-Shields, and what was perhaps not fully realised by shipbuilders, viz., the enormously increased expense of docks when the depth was increased. It was not so much the length or the beam of the ships which increased the cost, but the depth. While the cost of the dock increased almost directly as the increased length when the depth was increased the cost increased more nearly as the square or the cube of the extra depth. He thought that should be more fully realised by merchants, who eventually had to pay for additional dock schemes. It would simplify matters very much if a recognised limit of depth could be established, a reasonable depth of, say, 35 ft., within the next ten years. The minds of harbour engineers would then be relieved and their work greatly simplified.

Mr. Asa Binns said he had hoped that Mr. Palmer would have made some remarks on the construction of the new extension of the Royal Albert Dock, which many of them would probably visit on the morrow. Mr. Palmer, the speaker thought, had again effectively killed the barrage scheme. At the inception of the extension of the Royal Albert Dock Mr. Palmer was chief engineer to the Port of London Authority. That dock had an area of 65 acres, but the dimensions of the lock were interesting from the point of view of the discussion with regard to the size of ships. The lock was 800 ft. long, 100 ft. wide, and 45 ft. deep. He, the speaker, had listened with great interest to the remarks which Mr. Newell, the chief engineer of the Mersey Harbour Board, had made with regard to the sizes of ships to be anticipated, and he noted that he was somewhat pessimistic with regard to the arrival of the 1,000 ft. ship. It was ten years since the South Albert Dock was designed, and, if anything, the speaker thought the depth was too great. The length of 800 ft. he thought about right, but the width of 100 ft. was on the low side. With regard to Mr. Deane's paper "Cranage Facilities," they would see at the South Albert Dock about 60 of the 3-ton electric cranes of 65 ft. radius. Such cranes were very costly, and it was obvious that they could not be a directly paying proposition. They could only be paid for if part of their cost came out of the dock dues, river dues or tonnage dues.

There being no further speakers the authors of the notes were invited to reply, and Mr. A. R. T. Woods said that he had raised a hornet's nest about the barrage. In his paper, however, he had referred to the dockising of the Thames, and had said nothing about a barrage. There were other means of dockising rivers, besides barrages—such, for instance, as quays and wharves. He had spoken in connection with the loading and discharging of ships and of keeping them afloat by providing sufficient water, as was done at Hamburg, Antwerp, and other places on the Continent. He still thought that the quays and wharves on the Thames could be very much increased and utilised more. They could also be made to accommodate the large ships that came alongside the wharves and quays and turned round and got away quickly. As regards docks to be built for the size of ships in prospect, he thought they were getting somewhere near the limit, as suggested, and that there would not be very many more leviathans in the near future.

One of the great points in connection with the efficiency of docks and the efficient working of steamers, the speaker continued, was the quick turn round. It was no use having ships brought in and being able to discharge them in a few hours if the next boat that came along found the quay congested with goods. In this respect it was necessary for the railway companies to assist. On the subject of cranes *versus* winches and ships' gear the speaker referred to the new type of crane mentioned by Mr. Kirkpatrick at the morning session. This crane, Mr. Deane explained, would save much of the time usually lost in slewing, and there was no doubt that that was where the ordinary crane failed, in comparison with well-equipped derricks and winches. He had recently confirmed this at the London Docks, and had found that the time required for the turn round of a crane was 1 minute 45 seconds, as compared with from 2 seconds to 15 seconds for the winches. The saving in a day's work was therefore very considerable as was proved by the fact that piece-workers and dock labourers always preferred to use the winch, rather than the crane.

The speaker thought with regard to cargoes of a general character, such as bales, bags, cases, carcases, &c., that the cargoes would go where the transport was made easy by proper appliances, and it would therefore pay the dock authorities to provide them. Another difficulty occurred in connection with the loading of the steamers in the British Isles. The cargoes were varied in character, and therefore took a good deal of time in collection at the quay before loading could be started. These were points which the engineers and the dock authorities had to take into consideration when they were considering quay spaces, so that they would not be overcrowded. Reference had been made to a merchant moving his goods and living from hand to mouth, but this difficulty, the speaker thought, could be got over by imposing a heavy fine when the goods were left on the quay too long. Any port would be congested in a very short time unless some such step were taken. All these points should be considered by the authorities, to see if they could not get a quicker turn round, as that was the only way to make the ships pay the shipowner on the present high prices and costs.

Mr. H. J. Deane, who then replied, said he wished to apologise for Mr. Kirkpatrick's absence. The speaker thought that it would be said that the discussion had brought out many remarks of considerable value, but he wished particularly to refer to those of Mr. Newell, Sir Westcott Abell, and Sir John Purser Griffith. In regard to Mr. Newell's remarks, he thought he was right when he said that the trader was the person who really had the deciding influence. The question of dealing with ocean liners was a matter of considerable interest to him personally, and he was very much inclined to favour the view taken by Mr. Newell that it would be better to provide floating landing stages, and not large dock systems, for the accommodation of one or two mammoth liners. His own view was that the matter hinged on the amount of water that was available in the particular estuary, and the amount, or range, of tide. It was obvious that if they had a large amount of water without excessive dredging, and no range of tide worth speaking of, that it was very much in favour of the dry dock, or graving dock, and was also particularly in favour of the floating dock. That might sound rather anomalous; but in tidal waters, where there was a large range of tide, and most of the dock work was done during high water, if they were going to provide a floating dock to accommodate large vessels, they had to accommodate not only the depth of the vessel itself but also the depth of the floating dock. He did not think it possible to lay down a hard-and-fast rule as to which would be applicable to any port; each case would have to be considered on its merits.

Sir John Griffith, Mr. Deane continued, had touched a keynote when he referred to sinking funds. The speaker's view, and he thought Mr. Kirkpatrick would probably agree with him, was that many of the past failures of dock companies had been due to lack of foresight in providing a sufficient reserve fund to meet the inevitable expenditure at a later stage. In the early part of last century, large profits were made, and those profits appeared him to have been distributed without any proper provision for a reserve fund. He thought that if such provision had been made and an adequate reserve created to wipe out the capital cost, at all events of a certain portion of their undertaking, the finances of those companies would not have been in the deplorable state in which they

found themselves at the latter end of the same century. Mr. Binns, the speaker continued, referred to the new dock at the South Albert Dock, which was 100 ft. wide, 800 ft. long and 45 ft. in depth, but he had not mentioned that the width of 100 ft. was not fixed by the engineer; it was fixed by considerations of finance.

Coming now to the references to his own paper, Mr. Deane said that one of the first remarks made was on the question of hydraulic *versus* electric cranes. He did not think that question really arose from his notes, but as it had arisen, a few words on the subject would possibly be of interest. In his own view, the answer to the question very largely depended on how they were going to work the cranes. For ease of working there was no doubt that the hydraulic crane was far superior to the electric crane up to a moderate size. Moreover, when any shipowner or stevedore was allowed to hire the cranes and to work them with his own men he had no doubt that the hydraulic cranes were the most economical, despite the fact that their efficiency was lower than that of electric cranes. He had in mind the instance of a large number of modern cranes built in 1914, only one of which was worked by one particular man, who took great care of it. The result was that they had had no trouble whatever with that crane. There were a large number of the same type of cranes in other parts of the docks which could be used by anyone desiring to hire them, and those cranes had given endless trouble. Another point in regard to electric and hydraulic cranes was, that there was always a tendency among the stevedores, and those breaking cargo, to use the ship's cranes for dragging out cargo. The hydraulic cranes had a limited application, as they could not exert on the load, a pull greater than that for which they were designed, but in the ordinary electric crane the blow-out was set at something very considerably above the full load, which meant that the crane could be overloaded to the same extent without anything happening until the fuse blew out. That was a very undesirable thing in the speaker's view, because it meant that the crane, in effect, had to be designed for overload, and not for the normal loading.

The general question which he was hoping would be well ventilated was that of the design of the crane, as to whether the swinging or slewing, crane was the right type. His own view was that the limit of the slewing crane had now been reached, and that it was necessary to design something of a much more continuous character, although it would not necessarily be a conveyor. In a modern crane of 30 cwt. to 3 tons capacity, the structure was actually under stress for only a very small portion of its life, but if a crane could be designed in which the structure was subjected to the full load for the whole of its life it would be an ideal type. If they could design a crane so that as soon as one load was out of the hatchway another could be lifted from the bottom of the hold, he thought they would be near to a solution of the problem. They would then be able to deal with the increased cargo density. Moreover, with the aid of the shipowners, who, the speaker thought, should provide greater hatchway accommodation, they ought to be able to handle the loads in a much more expeditious manner than they did at present. The special type of crane referred to by Mr. Kirkpatrick was designed to a large extent in conformity with the views just expressed by the speaker, and another type of crane had recently been designed by Mr. Walker, one of the assistants in the Port of London Authority, of a somewhat similar character, in which the total weight of the crane was very considerably reduced, as also were the moving parts and the number of motions.

This concluded the joint session of Sections II and V, and after passing a vote of thanks to the authors of the three Notes, the proceedings of Section II alone were continued under the chairmanship of Sir Maurice Fitzmaurice.

SECTION II.—HARBOURS, DOCKS, RIVERS AND CANALS.

At the conclusion of the discussion on the papers read at the joint meeting of Sections II and V, the agenda of the afternoon session of Section II, dealing with harbours, docks, rivers and canals, was proceeded with. Sir Maurice Fitzmaurice, C.M.G., occupied the chair, and the meeting was opened by Mr. G. FitzGibbon, who read a note dealing with the subject of reinforced concrete for wharves and breakwaters. At the conclusion of his note, which is reproduced on page 73 of this issue, Mr. FitzGibbon suggested that the subject of the caisson method of construction for deep-water wharves and breakwaters was one which might well be discussed, and pointed out that it had been in vogue in Canada for centuries in the shape of crib work. He stated that quite recently a great deal of the new work at Montreal and elsewhere had been carried out by means of cribs, and that cribs were nothing more than timber caissons. In the case of Montreal they had constructed as much as 1,000 lineal feet of completed quay, about 61 ft. in height from top to bottom, in a single season, some of the cribs being about 60 ft. in length and 45 ft. in width. He recommended caissons as a rapid and economical method of construction.

Notes were then read by Mr. F. E. Wentworth-Shields on the best method of protecting reinforced concrete from marine deterioration, and by Mr. L. H. Savile on the reasons for the deterioration of reinforced concrete structures above mean tide level. These two notes are given in full on page 73 of this issue. At the conclusion of his paper Mr. Savile stated, with regard to the porosity of concrete, that Mr. Carruthers had made rather an interesting experiment with a glass jar, which was three-quarters filled with water, and had a stopper of neat-cement placed in its mouth. This was left for some months, and noted from time to time. After five months it was noticed that the level of the water had lowered about a quarter of an inch. This, he thought, clearly showed that even with neat-cement, 1 in. in thickness, the variation from day to day between day and night air temperatures would reduce the level of the water, which must have worked its way through that slab of cement.

The general discussion on these three notes was opened by Mr. C. S. Meik, who said that the bulk of reinforced concrete construction in England had been carried out with square piles. He had, however, come to the conclusion that square piles ought to be avoided between wind and water. There was no difficulty in making concrete perfectly sound and keeping it sound below water or when it was quite dry. The difficulty was to prevent deterioration at and near high water level. No doubt the reasons given by Mr. Savile in this connection were technically correct, but he thought it all boiled down to this: that it was the water opening the pores of the concrete that allowed the air to get in and rust the steel. If they excluded oxygen from the steel no rusting took place. The difficulty with the square piles was that the corners cracked and came off. He had recently come to the conclusion that the proper thing to do with those piles was to coat them with a cylinder between wind and water. Another way was to use round piles, which were less liable to go than square piles.

A further point to which he desired to direct attention was the thickness of the concrete. In the old days they used a covering of from 1 in. to 1½ in. That was quite out of the question now. If they wanted to give a pile a moderate chance of life they must have 2 in. of concrete, and even more. Another point he would like to make was that below low water all bracing should be avoided. It was difficult to put in, and once in, they were not sure that it was really good. He would prefer to see a pile even 30 ft. in length unbraced than to have bracing which they could not rely upon.

Referring to Mr. Wentworth-Shields' note. Mr. Meik pointed out that the author had given instances of attempts that had been made to arrive at what might be called "impermeability." He did not suppose that perfect impermeability would ever be attained; but there was no reason why they should not get a reasonable degree of safety in that respect. He did not believe in any of the special compositions. There was nothing better than cement itself, and he would suggest that for all work between wind and water nothing weaker than 1 : 1 : 2 be used, and above water level 1 to 4 or even 1 to 5; but he thought there was more chance of getting good impermeable concrete by increasing the cement than by using any of the other substances that had been introduced. In connection with the external coating of concrete he was quite at one with Mr. Wentworth-Shields regarding the experiments made with coal tar. Provided they could get the coal tar on the pile there was nothing to beat it. But it was not always an easy matter to get the tar applied between wind and water.

Mr. A. T. Walmisley remarked that in the papers dealing with reinforced concrete he was glad to see sufficient prominence given to the concrete. Many architects and others having to deal with reinforced concrete thought simply of the steel. They did not realise the great importance of impermeability. He thought that perhaps they should study electrolysis more than they had in the past. With regard to the quality of the concrete, he quite agreed with the remarks of a previous speaker as to having a good concrete on the surface that was exposed to the action of sea water. Regarding the point raised by Mr. FitzGibbon as to the advantage of caissons, the caisson, having a hollow centre, could be filled with a somewhat poorer concrete than that used for the outside. In conclusion, Mr. Walmisley said he had always maintained that reinforced concrete was not of the universal utility that many people believed.

Mr. H. Jackson mentioned two points of practical experience that he had come across in connection with reinforced concrete. The first point touched the cause of rusting. In one particular instance his attention had been drawn to pieces of really excellent concrete which had been detached from beams. On investigation he found that a small particle of unslaked lime had got into that concrete. About twelve months after the concrete was put in, the scoring-off took place. It seemed to him clear that in this case there had been absorption of water from the concrete, which they should look upon as having set, by the lime, which had expanded and blown off those pieces. It occurred to him: Did anything like that happen as between the steel and the concrete itself? His experience went to prove that it did not. Steel had not the power to absorb water from the concrete, and if there were rusting, it must come about as a consequence of the water, with the dissolved oxygen, passing to the steel through the concrete. That led him to the point dealt with by Mr. Meik, and he wanted to suggest to them that the reason why the square pile was less efficient than the round was simply a matter of permeability. It was difficult to get the square corners filled in closely with the concrete, and as a consequence it was highly probable that there was slight porosity. His own experience seemed to point to the fact that with proper care they could get concrete quite impervious. But they would always get a certain amount of breathing; they would always get a certain amount of external porosity. And it was the filling up of that little external porosity with the cement grout and with the tar which increased the resisting power of the structure.

Mr. John Hannay Thompson said that he had had experience of reinforced concrete since about 1903. The first work that he had anything to do with was a road and railway bridge under which the tide ebbed and flowed. The first year or two they did have a certain amount of failure, not in any of the main beams at all, but in the pier sides. Since that was remedied they had had nothing wrong with the reinforced concrete work at all.

In 1904 he constructed a deep water wharf about 400 ft. long. His experience of that wharf had not been so fortunate; but one must remember that at that time very little was known in this country of reinforced concrete. The work was built by contract; the contractor had never done any reinforced concrete work before. In a few years he noticed defects and had had them repaired; and he was glad to say that the work that he repaired was still perfectly sound. But above the work that he repaired, in the main beams, he found that other defects were developing. These had been caused by corrosion taking place in parts of the old steel work that had been left in, and which he could not get out without taking out the whole of the beam and the deck as well. He thought one of the dangers in reinforced concrete was that in the early days

they were told that they had got a permanent structure, and therefore after it was constructed they did not examine it particularly carefully for a very long time.

He was still constructing work in reinforced concrete, and he was quite sure that with a little more experience reinforced concrete work would prove quite a success. Work that he had done himself, with his own men taking an intelligent interest in what they had to do, could produce, and did produce, lasting work in reinforced concrete that required no maintenance at all. But of course in those cases they did not have the human element to consider. It was a very difficult thing to get men to do what one wanted them to do and what one told them to do, if they were at their work on contract.

Mr. H. A. Reed said that, in order to render the concrete impervious, the first thing to do was to consider the cement, which should have a high silicate content. The application of one or two coats of silicate of soda would also tend to improve the face and harden it against permeability. In 1912 he built a concrete pontoon. With the pontoon they could not get the same thickness on their steel as they could in pile work, a covering only 1 in. in thickness being employed. The concrete was made with cyanite. The proportions were 1 : 1½ : 3½. That concrete had been in sea-water now since 1912, and they never had to pump the pontoon out at all. No water got inside, and as far as one could see there had been no deterioration whatever between wind and water. He had some experience with ordinary concrete in contact with salt water, and had found that a sort of paste was produced. This he had analysed and found that it consisted of magnesia. Evidently the action of the sea water was that the lime had been taken out of the cement and been replaced by magnesia.

Mr. T. M. Newell said that the Mersey Docks and Harbour Board had one or two small structures of ferro-concrete, and these had exhibited the troubles that had been mentioned by other speakers, particularly between wind and water. In one case numerous cracks had also appeared above water level. But there was one point that had occurred to him when the structures were being erected. The steel was put into the moulds just as it was delivered from the rolling mill. It was not properly cleaned. In many cases the mill scaling was still attached to the bars. He thought that was one of the causes which brought about early deterioration in ferro-concrete structures. His own practice in ferro-concrete work had been to store the whole of the steel work in the open for at least three months before having it cleaned and put into the moulds, so as to get rid of the mill scale. He was sure, from experience he had had, that a good deal of the early deterioration was caused by the mill scale being attached to the bars.

Sir John P. Griffith said that he could not speak with much authority as regards ferro-concrete, but he was well acquainted with the deterioration of cement that was not impervious. The effect of salt water on anything in the nature of lime was the replacement of the lime by magnesia. He could not confirm too emphatically the words that had been spoken that day on the importance of the impermeability of concrete, especially in ferro-concrete work. If they could not attain that they were inevitably face to face with failure. The best way of overcoming the difficulty was, in his opinion, to use sufficient Portland cement in mixing the concrete.

Mr. H. Cartwright Reid, C.B., said there seemed a very general consensus of opinion that it was the breathing of concrete, particularly that which was frequently wetted and dried, that was the real cause of deterioration. Whether that could be overcome completely by attempts to put more cement in the concrete, or whether it would be necessary to surround the portion of a ferro-concrete jetty which was above mean tide level with some more impervious material, such as cast iron, was a question on which further investigation was probably necessary.

Referring to the note read by Mr. FitzGibbon, Mr. Reid pointed out that the author had rather attempted to find some other way of construction than that which had been usually adopted. The Admiralty had investigated that question, and were attempting to find some way of making ferro-concrete structures other than by the imitation of wood. Mr. FitzGibbon had said in his paper that it was difficult to make under-water bracing in reinforced concrete. In two or three instances that had been done; and as far as their experience went, it had been successfully done by casting on shore diagonal bracing with cylinders at the ends to go over the piles. These were dropped over in position, and the upper ends concreted into the deck. The lower cylinder was fixed to the pile by divers. Some system of that kind would probably eliminate the difficulty which was always experienced in constructing concrete where it was subject to tide. Practically impervious concrete could be made in a pile which was cast on shore. But when the concreting had to be done under the influence of the tide they had the utmost difficulty in getting the concrete to resist the breathing which had been alluded to. Mr. FitzGibbon had suggested that caisson construction might be both cheaper and more suitable for ferro-concrete works. The possibilities of this form of construction had been investigated, and they had come to the conclusion that it would cost at least 25 per cent. more in money and 25 per cent. more in time.

Mr. C. H. Sandeman said he considered that Mr. Wentworth-Sheilds' remarks regarding the penetration of air and water through good concrete were possibly liable to be a little misleading. It seemed to the speaker that good concrete must be concrete which was incapable of passing air and water. It had fallen to his lot to advise in a great many cases of pervious concrete, but he had never had the least hesitation in using reinforced concrete, as he knew that it could be proportioned so as to prevent any percolation. Whilst being entirely in agreement with Mr. Wentworth-Sheilds on the subject of rich concrete, he thought there was a tendency to overdo it. He thought Mr. Wentworth-Sheilds' proportions, such as 1 : 1 : 2, were misleading. For years past he (the speaker) had used mortar in the proportion of one of cement and two of sand, and had found it to be absolutely impervious. It seemed to him that only in very exceptional circumstances would concrete stronger than 1 : 1½ : 2½ or 3 be necessary.

The points that had been mentioned with regard to external waterproofing of the concrete struck him as rather important. There was no doubt that oils and similar preparations would have some effect in preventing penetration through porous concretes; but as Mr. Meik pointed out it was extremely difficult to get these materials put on to the concrete. In the case of piles it might be done, but he did not see how it was possible to do it in other work which was being constructed on the site itself. Moreover, the oils would need to be renewed regularly to be of any use. The question of paint on bars to prevent their corrosion appeared to him to be almost suicidal, as where such a coating was used there must be a tendency to destroy the adhesion.

Mr. M. F. G. Wilson observed with regard to the question about under-water bracing referred to in the first paper, that he thought this would be rather a troublesome thing to do in ferro-concrete. He had not tried the system which Mr. Cartwright Reid referred to, but he thought the difficulty would be to drive the piles sufficiently accurately. His firm were carrying out some reinforced jetties in the East, where there was practically no tide at all, and they were doing the under-water bracing there by means of steel fixed to the piles by clips. That was making a really satisfactory bracing.

Then with regard to using floating caissons, that was a question they had very often gone into, and it was purely a matter of cost, and whether the site was suitable. They had to build the caisson, and to float it; that was rather a troublesome thing to do, especially if there was not a very considerable amount of water. They could not compare concrete caissons with timber crib work, which was very largely used in Canada. There they could build the cribs up in comparatively shallow water and float them out. But they could not do that with a reinforced concrete caisson.

Mr. C. H. Colson said he wanted to suggest to those present that one of the troubles which they had to deal with had been due to the fact that the majority of jetties up to the present time had been merely copies of timber jetties. He suggested that this was wrong; what they wanted to do was to adopt new designs for new medium and, as far as possible, to assemble the whole of the material into large masses, so as to do away with the necessity of under-water bracing, and also to reduce the probability of rusting. There was one other thing that had not been mentioned at all which he thought might possibly be of some good in the future. They had been talking about the possibility of stopping the steel from rusting. He was not sure that they would not come to using steel which would not rust, and there might be possibilities in the employment of a low-percentage chrome steel.

Mr. R. Peel Mears drew attention to the influence of the steel form. Wherever he had seen concrete plumb against the clean steel forms, he had invariably noticed there was a very much harder and more impervious skin on it than he had seen obtained from timber. He was inclined to think that if steel forms were used for structures subjected to tidal action, the resulting skin would protect the steel and prevent any percolation.

Mr. John F. Sides remarked that it seemed to him the previous speakers had been confusing two different degrees of impermeability. As far as the experience of his company had gone there was no difficulty in getting impermeability to an extent which would retain water, even under heads of about 50 ft. They had made a pressure culvert of 2 ft. 6 in. diam. carrying a 50-ft. head, and only 4 in. thick, and that had been made impermeable to the degree that there had been no visible water on the outside. That was all right as far as its purpose went, but it seemed to the speaker that the degree of impermeability they wanted to get for protecting the steel in marine structures was a much higher degree than that, and he did not think any experiments made on the lines which had been suggested would be conclusive. If they broke a piece of concrete, no matter how well the aggregate was proportioned, there were quite considerable voids in it due to air bubbles. When that culvert of which he spoke was being constructed they made pipes in 9 ft. lengths cast vertically; as each length was cast it was tested under pressure, and in every case the top 6 in. or 8 in. of the pipe showed considerable leakage which disappeared in about a day or so; but that showed that a head on the concrete and considerable working did get rid of a lot of the air holes. A friend of his had suggested that the way to get dense concrete was to get rid of the air, which he suggested was there before the concrete was mixed, and that if they partially exhausted the air before these bubbles were formed, they might be got rid of. He had never had any opportunity of testing this plan, but he saw no reason why it should not work.

The one other subject he would like to mention was the aggregate. It seemed to him that to get a perfect concrete they wanted an aggregate which contained particles of every size between their biggest and their smallest. That was, they must have particles which varied gradually between the biggest hole in the screen and the concrete cement.

Mr. F. E. Wentworth-Sheilds, in replying to the discussion on his note, said that Mr. Meik had pointed out a very interesting fact: that square piles appeared to crack more than round piles. It was a fact that a square pile would crack at the corners, whereas, for instance, along a wall of concrete they might find no cracks except at its corners, or where there was an external arris of some sort; but if they could open that wall of concrete, they might find that the steel had rusted, although being behind a surface and not behind a weak corner it had been unable to crack the concrete off.

With regard to electrolysis, it was quite possible that that was one of the contributing causes of the difficulties that occurred in reinforced concrete; but judging by American experiments one was rather brought to the conclusion that the amount of damage done by electrolysis was almost negligible unless the pressure of the current passing through the reinforced concrete was very high; and, of course, usually the pressure of stray currents was not

high. One of the speakers had suggested that good concrete was quite incapable of passing air or water. There he joined issue with him entirely. He was perfectly certain that there was no such thing as an absolutely impermeable concrete. But experience did seem to show that if it was rich in cement, permeability was lessened to such an extent that the concrete became safe. As he mentioned in his paper, what they did want badly—and he hoped that the Sea Water Deterioration Committee would help them—was that some standard of impermeability should be laid down. No concrete could be impermeable, but they would like to have a practicable test which could be easily applied in their daily work, to show that the concrete used conformed to a certain definite standard, and, therefore, was likely to prove satisfactory, even in important work like reinforced concrete for marine structures.

Mr. Savile had suggested that a lot of the trouble might be due to working under heavy loads. In that connection it was interesting to note that at Southampton there were two structures that had been put up at the same time. One was a jetty to carry very heavy cranes which were constantly at work. Alongside of it was a wharf which carried practically nothing at all. There had been deterioration in both. They were both erected about 20 years ago. But it must be admitted that the jetty which had the heavy cranes upon it had suffered by far the most. Near both jetties at Southampton was another jetty which was older still; in fact, he thought he might say the oldest in this country. It was built in 1899, and that was in absolutely perfect condition. There was not a sign of blemish on it anywhere. What the cause of it was he did not quite know. Again they wanted the Research Committee. But he rather suggested that it was largely because it was built with a rich mixture very carefully mixed and put in as being the first work of the kind carried out in this country, and that this was really the cause of its undoubted success.

Mr. L. H. Savile, in reply, said that from what Mr. Meik and one or two others had stated, it seemed to be generally accepted that most of the deterioration in ferro-concrete piles took place between wind and water in the same way as in the old timber piles. Although that was true to a certain extent, where they did get trouble with ferro-concrete structures which they did not have in previous constructions was in the portion of the structure above high-water altogether. There was no doubt that deck beams had sometimes gone very badly, and it was rather difficult on the face of it to understand why that was so. It was only comparatively recently that they had realised how some of those deck beams had been going; it was a portion of the structure which was not, in the case of ferro-concrete, very often suspected.

SECTION III. MACHINERY.

AT the opening meeting of this section which was held in the spacious library of the Institution, the chair was occupied by Captain H. Riall Sankey, C.B.

RECIPROCATING AND CENTRIFUGAL PUMPS FOR WATER WORKS.

Mr. Hugh Lupton read his paper making a "Comparison between Reciprocating pumping engines and turbo-driven Pumps." This we reprint on page 74, of the present issue.

The discussion was opened by Mr. R. H. Allen, who observed that the water works pumping engine was a very fine piece of mechanism, possibly the finest in any branch of Engineering. It was, therefore, a compliment to the modern turbo-driven centrifugal that it should be considered worthy of comparison with such a rival. The result was highly encouraging, even if in waterworks service the centrifugal plant was still less economical than its predecessors. One point he would make was that where space was valuable, the turbo-driven centrifugal had great advantages. Occasions might arise in land service, and had already arisen in the Navy. In the latest ships of the E class, for instance, there was no room for reciprocating pumping engines and his firm had accordingly installed vertical spindle turbine driven centrifugals. These compared favourably with the reciprocators in steam consumption and efficiency, and beat them completely in respect to weight and space occupied. He did not know whether water works provided the best field for turbo-driven centrifugals, but so far as high speed reciprocating pumps were concerned his firm had found the centrifugal to be the better type. The tendency certainly appeared to be to adopt the centrifugal more and more, and he thought that ultimately it would completely displace the reciprocator, and that the day was not very far distant when the builders of the latter type would have themselves to scrap their patterns.

The next speaker, Mr. J. H. Barker, observed that he had the privilege to be associated with Sir Charles Parsons as far back as 1889. The small toy of that date had since developed, until it was considered worthy of notice and comparison by builders of the most efficient class of reciprocators, viz., pumping engines. The development of the latter had taken 216 years, the first steam pumping engine having been erected in 1705. The author had been, he thought, a little unkind, in commenting on the breakdown of a 10,000 h.p. turbine, owing to the failure of a small subsidiary part, external to the turbine proper. He might be reminded that by a similar failure extraneous to the engine itself the reciprocators of the City of Paris were in a few seconds converted into scrap, what was breakable being broken, and what could not be broken was bent. Mr. Lupton had referred to the question of repairs, but it should be remembered that the reciprocator required twice as much labour to run it, as did the turbine, and that when this was taken into account the labour cost (inclusive of repairs) of the two machines would not be very different. He suggested that turbines such as were installed at Bristol could quite well be attended to by firemen. In fact, in some large electric stations, a single man sufficed to attend both to turbines and boilers during the night, and it was no uncommon thing at collieries for the ventilating fan to be run by a crew consisting of a single man at the engine and another at the boiler. He would not at that meeting enlarge on the saving of oil, and the cleaner feed, associated with the turbine, but in regard to fuel he would concede all that Mr. Lupton claimed. At the small output of 150 h.p. or so, the turbo-driven centrifugal could not compete with the reciprocator in the matter of coal consumption. But this was not the sole consideration, and in many cases the adoption of the turbine was justified by the greatly decreased capital expenditure which compensated for the extra cost of coal. As regards endurance the author had credited the turbine with a life of 15 years and the reciprocator with one of twenty-five years. If he had credited both with the latter life, the total annual cost of the turbine would be reduced from the author's figure of 1*l.* 13*s.* 4*d.* to 23*s.* The author had moreover neglected the item of the cost of foundations and buildings. Those required for the reciprocator would cost about 15,000*l.*, the corresponding figure for the turbine being 5,000*l.* Adding interest and depreciation charges on these amounts the total annual cost of the reciprocating pumping engine, with its buildings, came out to about 15*l* 13*s.* 4*d.* per water horse-power as compared with 2*l.* 8*s.* for the turbine plant and its buildings. This was a highly important matter to-day, when even municipalities issued 6 per cent. stock at 95.

Mr. H. Davy, who followed, said that the inefficiency of the turbine as compared with the piston engine was due to the fact that in all practical applications of power, velocity-energy was less efficiently utilised than pressure energy. The steam turbine only approached the best results obtained with reciprocating engines by working with a much greater ratio of expansion. Moreover, with velocity-energy the waste increased very rapidly with variations in the output. He thought that Mr. Lupton would have emphasised his argument had he compared the two types when working with varying loads.

Mr. Arnold Maude observed that the breakdown of a steam turbine through the fracture of an oil pump spindle, as instanced by the author, was impossible with modern designs, since on any failure of the oil supply a modern turbine automatically shut down. As regards the efficiency credited to the centrifugal pump this was reasonable for heads of 70 ft. or over, but for lower heads, efficiencies of 83 per cent. could be guaranteed, and even higher figures had been quoted. Again, whilst the engine was debited with a depreciation factor of 10 per cent., the turbine was debited with one of 15 per cent. In view of the fact that it had no wearing parts, and maintained its efficiency over very long periods, was this distinction justified? He knew of one case in which a turbine-driven centrifugal was still running after 10 years' service, during which there had been practically no repairs or replacements. Objection had been taken to 15 years assigned as the life of a turbine. The conclusion was sound, as turbines would last much longer than that, but in view of the rate at which the efficiency was being improved he thought present designs would probably be obsolete in 15 years. Some Continental firms were even now quoting remarkable figures which, if substantiated, would make obsolete those given in the paper. As regards variable loads, he would point out that if the speed could be varied to suit the duty, a flat efficiency curve was obtained over a very considerable range. On the other hand, when centrifugals were driven by alternating current motors there was a sharp peak in the efficiency curve.

Captain Sankey, before calling on the author to reply, asked him to elucidate further his comparison between piston speeds and speeds of revolution of turbines, as he did not himself see the connection. He recalled that in the early days of the high-speed engine, a well-known engineer had asserted that these engines must have a shorter life than the slow-speed type, since he said that the wear was proportional to the piston speed. This critic was then very much astonished when it was pointed out to him that the piston speed of the high-speed engine was actually less than that of its rival.

In reply, Mr. Lupton admitted that where space was restricted the turbine plant had a very great advantage. In water-works, however, there was generally ample space. As regards liability to breakdown, he had been connected with turbines for many years, and his experience was that failures were very much more frequent in the present state of the art, than were failures of reciprocating engines, which really were practically unknown. Since he had written his note he had received from the makers of the Milwaukee engine some data as to its endurance. It had been at work for over 30 years, during which it had made 210,000,000 revolutions, and had worked 162,000 hours. There had never been a major repair during the whole of this time. It had, however, been lately taken down for examination, and it was then found that the wear in the H.P. cylinder was just over $\frac{1}{4}$ in. and somewhat less in the intermediate and low-pressure cylinders. The diameter of the latter was 74 in. Mr. Barber had pointed out that turbines gave a condensate free from oil. This was true in general, but he had seen a turbine pump fitted with a grease separator just as if it had been a triple-expansion engine. With a suitable separator practically the whole of the grease could be removed from the feed, the residue left being under one grain per 1,000 gallons, and to such feed the boiler insurance companies raised no objection. Mr. Maude had suggested that the centrifugal efficiencies adopted in the paper were too low. They were based, however, on certain estimates given him. Of these he took the three highest, and then corrected the figure to correspond to three-quarter load at which the efficiency was just 6 per cent. less. He thought this a fair way of dealing with the matter, and was supported in this opinion by some actual test figures which he afterwards obtained.

THE UTILISATION OF EXHAUST STEAM.

Before the next paper was taken Capt. Sankey vacated the chair in favour of Professor W. W. Dalby, F.R.S., who called on Mr. E. R. Dolby to read his paper on "Exhaust Steam: its Employment for Power, Heating, &c." This paper is reprinted on page 74 of this issue. The author, before concluding, added that at Berlin the whole of the hot water required for some public baths

was obtained from a public electric generating station three-quarters of a mile distant. Here the exhaust steam was passed through calorifiers and the hot water pumped to the baths through underground mains. Several public buildings on the route were also heated by a supply drawn from the mains. He noted that steam for heating and drying purposes was often supplied at 60 lb. Such high pressures were unnecessary, and were adopted merely as providing a ready means of getting rid of the condensate. It would be much more economical to put in a vacuum pump.

The discussion was opened by Mr. Frank Biggin, President of the Institution of Heating and Ventilating Engineers, who observed that it would be well to consider not merely whether exhaust steam could be usefully employed, but also to what extent the production of exhaust steam could be avoided. Where power only was wanted, it would often be better to take a supply electrically than to attempt to utilise the exhaust steam. On the other hand, there were large installations where it had been found economical to generate the power required and use the exhaust for heating and other purposes. In colliery districts it would be difficult to use exhaust steam for heating or hot water services, as there were few buildings which could be conveniently supplied. The question of the relative efficiency of condensing as against non-condensing plant, where use could be made of the exhaust steam was being considered by a committee of the Institution of Heating and Ventilating Engineers, who to this end were collaborating with the Institution of Electrical Engineers. He might add that in one Metropolitan institution ordinary hot water boilers had been dismantled and a supply obtained by passing exhaust steam through calorifiers, with the result that a coal consumption of 4,000 tons was forthwith reduced to one of 3,200 tons, and this saving had since been increased.

Mr. R. W. Weekes, who followed, said that in 1909 Messrs. Eastons, of Erith, operated their works with highly efficient Schmidt superheater engines, taking 15 lb. of steam per kilowatt hour. As there was a large works demand for heat, they had, on the speaker's advice, replaced this engine with high-speed engines, exhausting at 60 lb. pressure, the exhaust steam being utilised in the works. These engines took 57·6 lb. of steam per kilowatt hour, but the coal consumption per annum went down from 12,800 tons to 8,000 tons. If electric energy were developed as a by-product to a steam heating plant, the fuel expenditure was just ½ lb. per kilowatt; whether the steam were exhausted at 8 lb., 10 lb. or 60 lb. per square inch, or whether the engine was or was not working at full load. In ordinary power station practice, non-condensing engines normally consumed 6 lb. of coal per kilowatt, and at the largest station in London the figure was between 2 lb. and 3 lb. In the case of one of the Metropolitan Asylums a separate generating plant had been removed, although the whole of the exhaust steam could be usefully used. The reason was that the whole of the staff was under the control of the doctor. The plant was operated in three shifts, during one of which the fires were banked. In an ordinary works no attendant would be required on this shift, but at these hospitals they required a man to be present who probably slept most of his time. Later on the doctor said it was too risky to have but one man there, so he put in a second to sleep with the first.

Mr. Payne, who followed, said the great difficulty in utilising exhaust steam was to find a market for any current that might be generated as a by-product. At certain process works, by substituting high-pressure boilers for the low-pressure boilers now in use, and installing electric generators, current could be supplied at 1*d.* a unit and still leave on the balance an annual profit of 10,000*l.* to 15,000*l.* after paying all expenses. This was well known to the proprietors, but there was no market for the current. If offered to a supply company or corporation, the latter might agree to work in parallel with the works generators, but insisted on receiving all current from the works free, whilst charging for any taken, so that the sole advantage gained was that of running in parallel with the public supply. If, on the other hand, advantage were taken of the fact that certain works could supply current very cheaply, and these were linked up with central power supplies, there would be obvious advantages. In one case, this suggestion had been adopted in connection with an important scheme, and had made just the difference between its acceptance and its rejection.

Mr. Watson said that the paper seemed to foreshadow a kind of public drainage system, which would take away exhaust steam from all kinds of power plant and utilise it. It seemed to him impossible to contemplate anything of this kind where towns already existed, but if the plan could be put into practice in connection with new housing schemes or new garden suburbs, where there were no existing vested interests in electricity or gas, many of Mr. Dolby's economies might be realised. For his own part, he had always held the ideal that some day all lighting, heating and power might be provided by high-pressure alternating currents supplied from generating stations in the colliery districts.

Mr. Edwards, who followed, said the utilisation of exhaust steam appeared to be mainly a civil engineer's problem, as the crux was the question of distribution, the mechanical engineer being able to make use of any supply available. He believed such schemes would pay. The electricity commission had proposed, by their super-power stations, to utilise 18 per cent. of the energy in the fuel, but in a certain workhouse in which hot water and heat were distributed, 30 per cent. of the energy in the coal was utilised in the winter, and 25 per cent. in the summer, and he thought still better results could be realised in an industrial area. Economy of fuel was a prime necessity, since if we went on increasing our coal consumption at the same rate as during the past 40 years, there would in 135 years, be no coal seams over 1 ft. thick left in the country.

Mr. Haydon said that Mr. Dolby had referred in his note to work done at Manchester, where the building of the Calico Printers' Association was heated by the waste heat from a generating station 600 ft. away. The building had 800 radiators in it, and 14 miles of piping. The maximum demand for heating and hot-water supply was 12,000 lb. per hour. Originally, the speaker had estimated that the back pressure on the engines supplying the exhaust steam would be raised by 2 lb., but the rise had never been more than 1½ lb., and in that case, heat was also supplied to another building somewhat further away. By increasing the pressure, vastly more heating could be effected with the same piping. The electrical engineer at Manchester had recently told him that it was intended to scrap old boilers at the Dickenson-street Station, and the speaker had suggested as an alternative that as the whole value of these boilers had been written off, that they should be recapitalised and the station worked primarily as a heating station, developing electricity as a by-product. Electrical engineers appeared to be obsessed with the idea of low generating costs per unit in place of regarding the question as a whole. If, on the other hand, they collaborated with heating engineers, much better financial results could be secured.

Mr. Herring said that they ought to realise the position with regard to the utilisation of exhaust steam for district heating. In America the plan had been a success but the conditions were different here. The subsoil of the streets of our large towns was crowded with conglomerations of water and gas pipes, drains, and electric light and telephone cables so that the construction of a subway for the 20 in. or 24 in. pipes, which would be necessary for district heating on a large scale, would be a very serious matter indeed. Moreover, the climatic conditions and the character of the buildings were not the same as in America. There in the northern district severe weather prevailed for a very long period, and this factor, combined with the high internal temperatures maintained in American buildings, implied that they could sell a much larger number of heat units per unit area than would be possible here. He had got out some figures which indicated that owing to this difference in conditions it would be necessary in this country to charge the occupier of a small eight-roomed house about 46*l.* per annum for heating service alone.

Mr. O. Pochobradsky said that the utilisation of exhaust steam had a special interest for steam turbine builders, but he thought that the field for heating and power production by exhaust steam was narrower than might be expected. As matters stood there was such a large quantity of low-grade heat produced that were it practicable to utilise it all almost the whole of our heating requirements would be met. The question, therefore, was not one of replacing condensing plant by non-condensing plant, but of combining both types so that the non-condensing were installed in areas where the waste heat could be used. He estimated that about three-quarters of our power requirements should be met by condensing plants and only the remaining quarter by the non-condensing type. There were great advantages where heating could be combined with power production. In the case of one engineering works where a modern plant had been erected by his firm to supply both power and heat, the annual saving, as compared with former conditions in which the power was furnished by a six year old condensing plant, amounted to 6,000*l.* per annum.

Mr. W. Patchell said that in America live steam heating had been adopted in certain cases because it was found that to distribute exhaust steam heat over a large area did not pay, but he did not think that either system would prove as profitable here as in America.

Mr. E. R. Dolby said he would be very brief in his reply. His chief point was this: They had had for a great many years a tremendous loss of heat units in the form of exhaust steam, or in the form of condensed water. He asked how could they stop that waste. A given works might not have any use for the by-product—the waste heat. Therefore he said the only way to make use of it was to put down pipe mains and pass it on to where it was required. Mr Haydon gave tham a very good example of what had been done in Manchester, where they were passing the waste heat from the electric generating station to the building of the Calico Printing Association. He had hinself given them an example in Berlin where the waste heat was put into water and sent to the public baths. There were plenty of possibilities in this country of the same kind. What he wanted to get adopted was some system of that kind. If one went down Great Smith-street one would see some public baths there with their own boilers, and not very far away an electric generating station which was wasting a terrific lot of heat.

SECTION IV.—MINING AND METALLURGY.

SIR ROBERT HADFIELD, Bart., who presided, opened the proceedings on Wednesday, June 29, with an address in which he stated that the first Engineering Conference had been held in 1897, this being followed by others in the years 1899, 1903 and 1907. He had always found these conferences of the greatest value. This year they had been especially fortunate, as they had present in London not only representatives from Dominions, Commonwealths, and other outlying parts of the Empire, but also a large deputation of important representatives from the United States. These visitors from our own Empire and from America were to be welcomed not as strangers, but as representatives of the great world community of Anglo-Saxons. In the terrible time we had been passing through as regards the entire cessation of coal output in this country, it gave us furiously to think when we read that the output of coal in the United States last year reached 645,000,000 tons, that figure including both anthracite and bituminous. With regard to other fuels the marketed production of petroleum in 1919 had been 377,000,000 barrels of 42 gallons each, the approximate weight of one barrel being 378 lb. The production of natural gas in the same year had been 639,000,000,000 cub. ft. The coal, petroleum and natural gas output for 1919 had been equivalent to 18½ trillions (American notation) of British thermal units, of which 84 per cent. had been from coal, 12 per cent. from petroleum and 4 per cent. from natural gas. The great stoppage in output between

1914 and 1918—for most war production had been practically waste—must be made up sooner or later or our civilisation would depreciate. After referring to the German iron and steel trade and its development, Sir Robert said the world was literally craving at the present time for a 100,000,000 tons of iron and steel. Speaking of corrosion, Sir Robert said that he doubted whether the very serious wastage of iron and steel which went on from year to year was realised. From this source alone there must be an annual wastage of 1½ per cent. to 2 per cent. on a rough estimated total of 1,860,000,000 tons of iron and steel produced in the world between 1860 and 1920, or allowing for weight of articles discarded which were of no further use, due to the effects of corrosion, then about 3 per cent. to 4 per cent. It would thus be seen that the amount required to make up these losses was very considerable. In regard to fuel economy, Sir Robert referred to the exhibits he was showing at the conference then being held by the Institution of Mechanical Engineers.

In the matter of the utilisation of water power he said that in view of the large application of electric energy so necessary for the engineer, for steel making and power purposes, it was interesting to speculate whence would be derived the power of the future from which electric energy would be developed for various purposes. Most of the members, and in many respects rightly so, had a great belief in the large amount of energy obtainable from what had been picturesquely called "white coal."

In view of the considerable development of the Niagara Falls, it had occurred to him that it would be interesting to know how much energy could be obtained from them; and he had obtained data showing that the horse-power for industrial purposes when utilising 60 per cent. of the average flow would be 2,700,000 h.p. at a head of 220 ft., and 3,720,000 h.p. at a head of 310 ft. At Niagara Falls only 695,000 h.p. had yet been utilised. Great development was going on at the present time at the Canadian waterfalls. Dealing with Scottish water-power schemes he said that one, the Lochaber scheme, was estimated to cost nearly 3,000,000*l.* The Grampian scheme also would be on a comparatively large scale; though they were both comparatively small alongside the power of Niagara. As a comparison Sir Robert stated that the total horse-power developed in the City of London (Metropolitan area) amounted to 2,055,000 h.p., of which 1,400,000 h.p. was used to develop electrical energy, 190,000 h.p. for working tramways and railways, while the balance of 465,000 h.p. was produced by steam, gas, &c. It was to be borne in mind that these figures represented horse-power expressed in terms of steam or mechanical horse-power. The energy already being utilised from the Niagara Falls was sufficient to furnish about half of all the horse-power used in the Metropolitan area with its 8,000,000 inhabitants.

THE EMPLOYMENT OF WATER POWER IN THE DEVELOPMENT OF THE MINERAL INDUSTRY.

This paper, by Mr. John William Evans, F.R.S., was then read in abstract by the author. We reproduce it on page 76, of this issue.

The discussion was opened by Mr. W. M. Morrison, who said he might claim to be one of the pioneers of the development of water power on a large scale. For many years he had advocated the advisability of directing much greater attention to the water power of our country and empire, and he was very pleased that a move had been made in this direction. The Water Power Resources Committee, appointed by the Board of Trade, had stated that in view of the immense water-power resources known to exist in the Empire and their commercial value, it was of urgent importance that adequate steps should be taken to promote the development of those resources. In Dr. Evans' paper reference was made to a certain number of water powers available in the Empire, particularly referring to British Guiana; but no reference was made to the marvellous falls of Kareto which were supposed to be larger than Niagara. So far very few white men had seen these falls, for they were situated in dense jungle. Dr. Evans had referred to the irregularity of water power, and that, of course, was the case to a large extent, but in many instances it was quite possible to provide adequate storage. In Switzerland they depended entirely on glaciers. Roughly they had about eight months full supply during the year and four months' very short supply, but for most metallurgical industries, such as aluminium, that had been found to be a quite sufficiently economical way of operating. The power roughly descended during the four dry months of winter to about one-third of the maximum power. In countries such as India there had been several large schemes developed where they put immense dams at the heads of valleys and formed artificial reservoirs. In our own country it was always possible without any great cost to dam up the locks through which the rivers flowed and thus obtain a storage flow for practical purposes. It was found that something of the order of from 60 to 90 days' storage was sufficient. He was particularly interested in aluminium, but there were numerous materials that might be produced by cheap power. He thought there was a great future for the electrolytic production of iron. Another metal was magnesium, and he thought there was a future for this if it could be produced at a reasonably low cost. In the Lochaber scheme with which he (the speaker) was associated the power developed was something of the order of 72,000 h.p., probably rising in wet years to 100,000—absolutely continuous 365 days of the year and 24 hours a day. When the power was fully utilised the annual output would probably be of the order of 600,000,000 units per annum. The largest power station in London was at Lots-road, where the maximum output was of the order of 160,000,000 units per annum. The large electric light stations of London ranged from 35,000,000 to 40,000,000 units per annum, so it would be seen that the Lochaber water power of 600,000,000 units was enormous. There were numerous other powers in Scotland which could and would be developed in course of time. Dr. Evans had referred in connection with aluminium to the raw ore bauxite; it had paid hitherto and would pay for a very long time to bring the bauxite to this country where one had the balance of the raw materials and cheap water power.

Mr. W. B. Whitney said that for a number of years he had been engaged on the construction of the Bombay hydro-electric scheme which presented a number of interesting features. But before turning to that part of his subject he referred to a lecture recently given before the Institute of Electrical Engineers on the magnetic separation of minerals and rocks of various kinds in which Professor Wilson of King's College had showed that practically every kind of stone and every mineral was affected by magnetism in a varying degree, so that undoubtedly that side of the use of electricity would come more and more to the fore in future. In regard to the Bombay hydro-electric scheme, he said the problem was to get 100,000 h.p. without any river. The method employed had been to collect the rain that fell on a very small catchment during the monsoon. A very careful study had been made of the rainfall in the district and some interesting conclusions had been arrived at. The scheme had shown the importance of making a study of rainfall because the variation was enormous over a very small space. But now there was a lake containing 7,000,000,000 cub. ft. of water. Great assistance had been obtained from the engineers of the Great Indian Peninsula Railway who had kept a rain gauge at one station for nearly fifty years. It had been found at that particular station that the rainfall varied from 70 in. to 200 in. The gauging before the works began had shown that it was the hill-tops which had the most rain, but after the lake had been formed this altered entirely and instead of the hill-tops getting the maximum rain they got the minimum while the lake had the heaviest rainfall. The question of run-off and evaporation was also very important. In England he believed the run-off was usually about 30 per cent., but where there was a very heavy monsoon, as at Bombay, they found the run-off varying from 70 per cent. in years of low rainfall to 90 per cent. in years of heavy rainfall. Evaporation was also very important. On a scheme with a thousand feet fall a loss of half an inch of water per square mile with energy being sold at a ½*d.* per unit would mean a loss of about 500*l.* per square mile. The loss by evaporation in India had been found to vary from about 8 ft. to 10 ft. in the East, but was only about 18 in. in jungle country. On the Bombay hydro-electric scheme the loss was found to be about 3 ft. during the year.

Mr. Theodore Stevens said that Mr. Evans had stated, "the energy of the Sivasamudra Falls had been utilised in the Kolar Gold Fields, and it was proposed to make use in the same way of that of the Victoria Falls on the Rand." He (the speaker) had been connected with the company that had carried out the contract for the Kolar Gold Fields. It had proved a very profitable and excellent piece of work. As to the Victoria Falls, these were nearly 600 miles away from the Rand, and no transmission of energy had ever been made, he believed, beyond 240 miles. At the present moment the problem in the States super-power scheme involved the experimental development of 220,000-volt transmission over 350 miles of line. It was 17 years since the Victoria Falls Company had been launched. "Victoria Falls" was a name which appealed to the public just as the Nile and Assouan dam would do, but it was a mistake to think it was possible to transmit energy such a distance. New York City was only 300 miles from Niagara, but got no power from that source. During the war we had paid between 4*l.* and 5*l.* a ton for electrical energy for melting steel. Of course, that was a vastly different problem from that of reducing iron ore. But at the end of the war we could not afford to go on paying that money. Dr. Evans had stated that 75,000 tons of pig-iron had been produced in Sweden in 28 electrical furnaces, but in the Swedish Board of Trade returns for 1919 they gave for the year 1916 an average of 6,400 tons per furnace while running only seven furnaces. The following year running eight furnaces, the figure was 8,400 tons, while in 1920 the production from 11 furnaces was given as 7,000 tons per furnace. Mr. Stevens was understood to say that other water-power schemes were of more importance than the Severn scheme.

Colonel Carnegie said he had been reminded very much of the difficulties experienced in regard to the supply of electrical power to factories in Canada during the war, and as to the question of the development of the use of power generated from water, he thought it was only due to the Cedar Rapids Company and to the Shawinigian Water Power Company to state that both had been large suppliers of electrical power and had greatly helped during the war.

Mr. Bailey said he would like to make one or two remarks with regard to the use of water power in the Merthyr Valley. Many years ago Sir Anthony Hill had used the water from the Taff River and water wheels to drive his iron and steel works. The result had been that in dry weather his works were nearly all stopped. Brunel, a great friend of Sir Anthony's, had suggested that the water should be turned into steam. Although at first averse to the project Sir Anthony had consented, and afterwards his profits had increased by leaps and bounds. He (the speaker) thought that in this country the only way to get power out of water was by turning it into steam.

Mr. H. W. Nicholson found that aspersions had been cast upon the Himalayas. He had been over the works of the Bombay Power Scheme, and it seemed to him that there they gambled on the rainfall. In the Himalayas there were enormous catchment areas. Reference had been made to aluminium. In the Geological Survey of India he had read of a proposal to export bauxite from the Central Provinces of India to America. If it was a commercial proposition to export the bauxite to America it would be a reasonable thing to take it to the Himalayas. He did not agree with the common opinion that the Himalayas were devoid of minerals. They were vast and little explored, but minerals existed there of which the existence was known. There were some of the finest and purest deposits of magnetite iron ore within 40 miles of one of the power stations he had been on,

and another on the Jhelum was in the midst of a very fine limestone formation.

Mr. A. E. Kitson said that Dr. Evans had pointed out that apart from the known uses with respect to the electrical reduction of copper and so on there was the possibility of getting the metal out of low-grade ores. This was a point to which sufficient attention had not been given. Many examples of damming of valleys were to be found in the Western African tropics, in Eastern Australia, Tasmania and New Zealand. Dr. Evans suggested coating the surface of the reservoir with a film of oil to prevent evaporation in the tropics. But there was a natural method by the use of a plant found in the African rivers known as the "water lettuce" or "cabbage." This spread over the water surface giving a protective cover. It grew easily and had not the disadvantage connected with a ground root growing plant, which would turn the reservoir into a swamp in a very short time. As regards the transmission of power it had been pointed out that 200 miles was the limit. In this connection the great cost of copper wire had to be considered, but aluminium could be used. This was very much lighter and cheaper, its only drawback being that owing to swaying in the wind the particles of the metal were inclined to re-arrange themselves, and there was a consequent tendency to brittleness. That could possibly be overcome. In West Africa there were large areas covered with auriferous gravels which were too poor to work in the ordinary way, but which would prove a rich proposition in many places if cheap water power could be applied. Hydraulicking and ground sluicing were the two means by which the widely-disseminated gold over large areas of the Gold Coast could be profitably extracted.

Dr. Evans, in replying, stated that in regard to treating bauxite on the spot, he believed it would be found possible to do this with the aid of electricity produced by water power. For instance, soda could by electric current be obtained from the salt of sea water. He had been very sorry to learn shortly before the lecture that the project for bringing power from the Victoria Falls to the Rand had been practically abandoned. It seemed to him that it was merely a question of the size of the cable, and if a suitable cable, having a small resistance could be made sufficiently cheaply, power could be carried 500 miles or more. With regard to the statistics about the Swedish output of electric iron, these had been supplied by our Statistical Department from the Swedish Record, but he would make a point of ascertaining how the discrepancy had arisen. It had been far from his intention to cast any aspersion on the Himalayas, he had only implied that their mineral wealth was not comparable with that of the Rockies or the Andes. Bauxite occurred in the Himalayas, there were important deposits in Kashmir. This variety differed from ordinary bauxite and required special methods to deal with it. There was also plenty of iron ore in the Himalayas and even some copper; but, so far as his knowledge went, the copper deposits were poor. He looked forward to a time when the water power of the Himalayas would be as usefully employed as that of any other part of the world.

Recent Development in Coal-Cleaning Processes.

This paper, by Mr. Robert Nelson, was then read, Mr. C. P. Sandberg occupying the chair. Professor Edser demonstrated the method of coal cleaning by flotation in a small apparatus in the room. We reproduce the paper on page 76. The discussion was opened by Colonel Rhodes, who asked whether it was proposed to crush the whole of the coal to below $\frac{1}{16}$ inch irrespective of its size, or only to deal with the very small coal that approximately was that size, say below $\frac{1}{8}$ in. diameter. He thought general experience had shown that it was possible to clean coal down to those sizes by means at present employed, and in some cases it was possible to clean the coal below those sizes by washing it with the larger sizes and the resultant mixture of large and small came to within the figures required by the industry. All knew that when they wetted coal the great difficulty was to dry it again, and the important point was how to dry the material below, say, $\frac{1}{16}$ in. diameter. Once that problem was satisfactorily overcome, difficulties disappeared, but it was the large outstanding problem.

Mr. Merz said the points raised by Mr. Nelson were very important, as they had a material effect upon the economical life of the nation in regard to the haulage of the coal and the disposal of the ash; but there was further the very important fact that in some cases the efficiency of consuming the coal was materially interfered with by the presence of the dirt in the coal; so that apart from the great saving of haulage and the saving of labour in disposing of the ash, there was an improvement of efficiency of between 5 per cent. and 10 per cent. in the actual consumption of the fuel. The results given in the table were very interesting, but he asked whether the fact that there was still a material amount of ash left in the coal—though very small compared with the original amount—might be attributed to the fact that the coal was not ground sufficiently fine? Or was there some other reason? The prevailing system of which we had had so much experience during and since the war, of having to consume these very troublesome fuels with such a large amount of dirt in them could not continue. It was to be hoped that the present stage in the coal industry would result in enterprising collieries who wanted to increase the demand for their products going into the question of supplying consumers with the fuel they wanted, and not with just what came out of the pit.

Mr. Foster said that he had expected some reference to be made to the use of Wilfly tables for the cleaning of small coal. This method had come very much to the fore in America where several big collieries had put down batteries of such tables. The tables took sizes of three-quarters of an inch downward. No special cleaning or crushing process was necessary, and 90 per cent. of free ash could be taken out by this means. It had been used in the metallurgical industry for removing vein stuff from ores. In the case of coal the coal was the lighter material, whereas in the metallurgical industry the reject material was the lighter. Otherwise there was very little difference required in the machine.

Mr. Nelson thanked Professor Edser for his demonstration of the flotation process. This flotation process was to deal with fine coal and not with all coal. He quite agreed that present methods very often gave very good results, and the second process he described in his paper claimed to do even better than had hitherto been done with nut coal. He agreed that the main difficulty was that of drying. This was actually overcome in the case of plants now running by a vacuum drier. He believed it was an importation from America, but it was efficient. The disadvantage was that it was rather a costly piece of apparatus. He had been interested to find Mr. Merz among those who were not prepared to lie down under the infliction of dirty fuel sent out from the pits. On the question which Mr. Merz had raised in connection with the table the reject contained 82·45 per cent. of ash, 2·75 per cent. of fixed carbon and 14·8 per cent. of volatile matter. That was because no process gave 100 per cent. efficiency and probably some of the coal was in the reject. There was also the possibility that some of the reject was shale, which would have a carbon content as well as a volatile content. (Mr. Merz: There is still nearly 10 per cent. of ash in the clean product.) Mr. Nelson replied that was so, but he imagined that was as low as the separation people regarded as commercially practicable. Probably better results could be obtained by further wash boxes. Of course the 10 per cent. would include the natural ash which was part of the coal and not foreign matter.

The François Cementation Process.

The last paper taken at the meeting of Wednesday, June 29, was that having the above title, by Mr. H. S. Ball. We reproduce it on page 77.

Mr. W. B. Whitney said that on a dam in India they had had a case which illustrated the use of cement in this manner. In excavating the foundation they had got right into the side of a hill and found a fissure which ran further on right into the hill. They grouted this up with cement under pressure by using one of the boilers from a crane having a two-way cock, letting the cement into the pipe and turning on steam. This had worked very effectively indeed.

SECTION VI.—WATERWORKS, SEWERAGE AND GASWORKS.

"The Utilisation of Waste Heat in Gasworks."

The first paper read before this section on Wednesday morning, June 29, was one on "The Utilisation of Waste Heat in Gasworks," by Mr. E. G. Stewart, the chair being taken by Dr. Charles C. Carpenter. This paper will be found on page 77 of our current issue. The discussion was opened by Mr. Charles Goulden, who congratulated Mr. Stewart on his paper, and called attention to the shortage of statistics relating to the use of waste-heat boilers. It was rather a blemish on the vertical retort system that so much of the heat used in the carbonisation of the coal went to waste, unless it was utilised in some such manner as had been suggested by Mr. Stewart. Water-gas manufacture again had led to the introduction of waste-heat boilers. The water-gas plant certainly was a very great convenience to those engaged in the gas industry, inasmuch as, particularly when it is accompanied by the carbonisation process, it provided great flexibility in working. Although they might increase the therm production from a ton of coal in the vertical retort system of carbonisation to a certain extent, it was only to a limited extent, unless they were going to have poor quality gas, because they had to do it at the expense of the calorific value, which was a distinct detriment. On the other hand, in the carburetted water-gas plant, although it might be a little expensive in use of fuel, they had means of utilising the coke from the coal-gas plant, and thus of very much increasing the production of therms per ton of coal carbonised, while the facility with which carburetting oil could be put into the plant made it possible to produce a larger volume of gas per ton of coal without necessarily decreasing the calorific value. Now by the use of waste-heat boilers they could bring the efficiency of the carburetted water-gas plant up very close to that of the coal-gas plant, i.e., up to 70 per cent., which, he thought, was a distinct gain. In fact, by the increase of efficiency the working of the carburetted water-gas plant was brought so near, in point of therms produced, to the coal-gas plant, that there was very little difference between the two.

Mr. F. H. Robinson said he thought it must be patent to all that in every gas works in the land considerable quantities of heat were being wasted. Coke in an incandescent state was drawn from the retorts, water was poured over it to cool it, and in many works it was passed along to another plant to be heated up again, which was a source of very great waste. As a result of his experiments he was perfectly certain that 12 per cent. of the heat of the coal was wasted in water-gas manufacture, and thought their efforts should be directed to eliminating those losses. Not only was there this loss, but one had also to consider the destructive effect of the rising steam from the coke on the steel work of the retort house roof; and also that it made working conditions unpleasant for the stokers.

Mr. T. S. Lacey said he was interested in the application of waste-heat boilers to carburetted water-gas plant, apart from that of "blue water gas." He would like Mr. Stewart to give some results of the working of waste heat boilers in connection with carburetted water gas plants. One could quite understand it would be simple to apply the boilers when they were using blue gas, but when they were using the carburetting process it somewhat complicated the matter, and under those conditions the results possibly might not be so economical. Anyone who had seen the application of the waste-heat boiler in the manufacture of blue gas must have been struck by the simplicity of the whole plant; but when it became a case of putting in boilers in connection with the flues of retort houses, the problem was one of an entirely different character.

Mr. Preece said he was very interested in the paper, because he had been intimately connected with the design of some of these waste-heat boilers. He had not had an opportunity of carrying out an extensive test in connection with such boilers with

a vertical gas retort installation, but he had conducted a test, covering a week, on producer-gas-fired furnaces, where the gases came away at about the same temperature and the same composition as in the case of vertical retorts. The temperature of the gases was 1,160 deg. F., and the actual evaporation was 2·89 lb. per ton of coal fired on the producers. An evaporation of 3·26 lb. per ton of coal fired was obtained with gases at 1,100 deg. F.; 2·7 lb. when the gases were at 1,000 deg. F. and 2·27 lb. when at 900 deg. F. Of course, when 850 deg. F. to 900 deg. F. was reached the boilers were of very considerable dimensions, which was rather a handicap; but there was no doubt that the economy when the gases were about 1,000 deg. F. to 1,100 deg. F. was extraordinarily good.

Mr. Samuel Glover suggested that it was one of the most distressing sights in the process of carbonisation of coal in gas works to see the loss of the energy, which was occasioned by the unscientific handling of the incandescent coke, and the associated damage and nuisances that were caused. If in other processes of carbonisation, heat were recovered, then the other processes of carbonisation started with an advantage. Heat was thereby available for the heating of the retorts, for generating steam in certain boilers that were adaptable to such a process, or in some other way. He desired to emphasize that it was the business of the gas engineer to utilise all the heat-energy in every ton of coal he handled.

Mr. R. E. Gibson asked whether waste-heat boilers in connection with water-gas plant had ever been used without any auxiliary supply of steam to start up the plant. It seemed to him it would be very difficult to work unless some steam supply were available at the commencement.

The Chairman said in all these matters what as engineers they were faced with was the problem of doing something because it was worth doing, and not because it was an ideal process. He was very much impressed by the conclusions which Sir George Beilby had drawn, which practically amounted to this, that at the present moment—at present prices, at any rate—it would not be an economical proposition to carbonise coal so as to separate its various by-products and utilise the heat in that way. Sir George practically told them that the most economical heat in the present circumstances was to be obtained by burning raw coal. There was another question with regard to the extent to which regeneration should be carried out, speaking not of the regeneration brought about by the use of a water gas plant, but the regeneration as applied to the retort settings. There was an important gas Company in which the great bulk of the retort settings were not provided with regenerators at all. The advantage of that, when fuel was cheap and coke was cheap and very much of a drug on the market, was that they were able to have practically all the advantages of gaseous firing without the very heavy capital expenditure. They knew of course that they could, by the addition of a very elaborate system, carry the process of recovery very much further than even with the best types of setting; but whether that was economical depended upon circumstances and especially on the capital cost. The Zurich plant was a particularly interesting one, and he would not like those present there to-day to go away with the idea that it was simply a waste-heat recovery process; he did not understand it to be that himself. One of the important things they were face to face with was the production of a high-grade coke. They knew that the amount of water that coke contained was variable, but some of them felt very strongly that coke should contain no water at all; and it coke were cooled in an arrangement of the kind that had been worked out for Zurich, it would be possible to produce a bone-dry coke, just as everybody was very keen to produce a bone-dry sulphate of ammonia.

Mr. E. G. Stewart, replying, thanked those who had taken part in the discussion. Mr. Goulden had seemed to be of the opinion that if one put a waste-heat boiler on the chimneys of retort houses it would probably be out of action a portion of the year, and, therefore, the capital would be wasted. As to waste-heat boilers for carburetted water gas plant, such boilers were being worked in America fairly satisfactorily. A waste-heat boiler on a carburetted water-gas plant should be a tubular boiler which had two sets of tubes, and there must be two cylinders. The difficulty arose that if the oil was over-cracked or under-cracked, in a very short time the tubes of the carburetted gas boiler became filled with either soot or tar, and it was necessary to clean them out pretty frequently. As a rule the boiler worked well, and under good supervision he believed it did not give a great deal of trouble, but it necessitated four stack valves on the set, which has to be used under varying conditions. They had to remember that the average waste-heat boiler only had a drop of anything from 700 deg. F. to 1,000 deg. F., whereas the ordinary type of boiler with a fuel fire had 1,600 deg. to 1,700 deg., which, of course, made an enormous difference in the capacity. The corresponding evaporations per square foot of surface were as about two to five as between the waste-heat and the ordinary boiler. He supposed Mr. Robinson was referring to the more ideal system of complete gasification whereby the hot coke passed straight into the water-gas generator without having to be cooled; but, of course, as things stood at present he did not see any chance of completely gasifying all the coal. They had not got down to 360 B.T.U. per cubic foot as the standard gas, and they were bound to get these losses all the time from the hot coke which was necessarily pushed out but not gasified afterwards. Waste-heat boilers were now being fitted on most vertical retorts, and it did have this advantage that instead of having the waste-heat in two places, it was in one, and therefore it could be recovered more efficiently. He believed that it was possible to recover about 24 therms to the ton in a vertical retort with the coke being cooled; this represented nearly as much heat as it was possible to get from the hot coke and the waste-gases of an ordinary retort setting with recuperation. Mr. R. E. Gibson had asked whether it was possible to apply waste-heat boilers to water-gas plant without auxiliary steam, the difficulty being as to the draught on the fire. If one had two sets of waste-heat boilers and one running, of course there would be no difficulty at all; as a steam jet could be used to make the draught otherwise an electric fan could be employed.

DESIDERATA IN THE QUALITIES OF TOWN'S GAS.

The second paper to be read before the Section was "Desiderata in the Qualities of Town's Gas," by J. S. G. Thomas, D.Sc. This paper we reprint on page 78. The discussion was opened by Mr. Ralph E. Gibson, who said he was very much interested in the paper, bringing before them, as it did, the various points that were so much to the fore at the present time. He quite agreed that sulphur compounds were undesirable; in his works they had sent out a very large quantity of water-gas, which reduced the percentage in the finished gas very considerably, and they did not think in their case, at any rate, it was necessary to eliminate the sulphur. With regard to inerts, he quite agreed with the views expressed; that it was undesirable to deliver gas that had no value for heating purposes. They did require freedom at the present time in their manufacturing operations, and it would be a mistake to legislate with the object of restricting the percentage of inerts. Naphthalene was a very troublesome constituent, and he believed in extracting it to a certain extent; he was not sure whether it was necessary to extract it entirely. Cyanogen was an undesirable constituent, but the effects of cyanogen were not fully known and were out of sight; he thought there was a big field for research in the direction of seeing how far cyanogen could be dealt with.

Mr. Lacey, referring to the question of the composition of gas made not purely from coal but from various sources, said as an old manufacturer of gas there was no method of making gas of more constant quality and uniformity than that of using coal. If gas were being made from the complete utilisation of coal or by any other method which the manufacturer might think was for the consumer's benefit, it would be desirable to possess a calorimeter.

Mr. Samuel Glover said he thought that at last the gas industry was showing signs of vitality for which it had not yet received full credit. He wished to call the attention of the meeting to the fact that Dr. Thomas's contribution did give some credit to the gas industry for looking for truth, and to being able to estimate it when it got it.

Mr. G. Evetts, of Westminster, said the recent coal dispute had taught the coal industry more in the past three months than they had learned in the preceding ten years; this was not due to ignorance on the part of the gas-worker, but was because he had not had the opportunity of experimenting such as he had had during the past three months. The use of blue water-gas had proved its efficiency both from the point of view of the conservation of coal and the saving of many companies during the last two months from absolute disaster. There was a case in the London district where 100 per cent. of water-gas was being sent out, and to-day 50 per cent. and 75 per cent. were quite common. The experience they recently had would be of the utmost value to them when they started seriously making gas under the Gas Regulation Act of 1920. They had also to view the question now from the thermal point of view. The probable high price of high-grade coal in the near future, and the relatively low price of coke which would have to compete, he presumed, with industrial coal, would probably tend to make the manufacture of water-gas more attractive in the future than it had been in the past. That tendency would be helped by the lowering of the price of gas oil, which would result in bringing carburetted water-gas into use. It looked as though in the future coal would be stretched to its utmost limits for the manufacture of coal-gas, and there would be a large percentage of water-gas possibly of a higher calorific value than the coal-gas itself. Dr. Thomas had mentioned the wide limits of actual composition which could be covered by the same calorific value. He did not know whether Dr. Thomas regarded it as a desirable thing with regard to town's gas to take advantage of that latitude, but he personally did not think they ought to work along those lines at all; they ought to work from the point of view that if they looked after the composition the calorific value would take care of itself. There was no doubt that if they looked after the purity and composition of the gas, and kept the pressure right, they would retain the domestic consumer not only for heating but for lighting.

Mr. Thomas Goulden said he felt the lesson which Dr. Thomas wished to inculcate was that they should send their gas out as pure as possible. He was sure that that should be their aim; but they had of course to work up to their ideals only so far as might be economically sound. He had sulphur compounds particularly in mind. He would like to see the sulphur percentage very low indeed; but they had to consider the price at which they could get it, which was the difficulty at the present time. With regard to naphthalene, cyanogen, and all those other deleterious constituents that were no good to anyone, let them get rid of them as much as they could. Cyanogen, although it was not an immediate cause of trouble, was one that would give trouble in the long run, affecting the meters, mains and fittings; he was in favour of extracting it wherever possible. He felt the same with regard to naphthalene; let them make gas with as little naphthalene as possible, but when they had it, they should get rid of it. He urged them to get rid of all impurities, which were not combustibles. With regard to the combustibles themselves, he thought the appendix was particularly valuable; one of the points which it showed was the higher thermal value of carbon-monoxide as compared with the other main constituents of gas. He had noticed in the melting of metals that a larger percentage of carbon-monoxide gave very great facility and economy. So long as carbon-monoxide was not in undue proportions, it seemed to be all to the good. He entirely agreed with the author that in this matter of the regulation of gas manufacture and supply we should be free from restriction with regard to inerts, and also with regard to carbon-monoxide. It was one of the greatest mistakes possible to send out a gas with a large quantity of inerts, which were no good to the consumer. He did rather protest against the suggestion of stretching the coal-gas and making it up with oil when oil was cheap; to his mind that was not the right way of making gas at all. He would vastly prefer to

make a good quality coal-gas, and then add to that a lightly carburetted water-gas in order to make up. He believed strongly in making the very best quality of gas they could. It was difficult to make gas of a constant quality; they never could do that. At the present moment there was much experimenting and trial going on with regard to gaining greater thermal capacity in dealing with coal, but it was quite clear that they were not anywhere within approachable reach of a standard gas. Until they could have this standard gas the objections to varying qualities of gas could be overcome by each undertaking supplying gas as far as it could of a constant quality. It was the largely varying composition from day to day that upset the consumer. An undertaking could adjust all its appliances for its declared value and composition; then let it go on supplying that composition until it next declared another composition; it could then alter the appliances and go on steadily again.

Dr. Thomas, replying, said he was not aware that naphthalene could be looked upon in any way as a valuable constituent of town's gas; it added practically nothing to the illuminating power under ordinary circumstances, and it added practically nothing to the calorific value. He was in entire agreement with him with regard to the question of cyanogen. He ought, perhaps, to have said that naphthalene should be avoided entirely, but he did not know of any process of gas-making which avoided the production of naphthalene entirely; if it was produced he thought they all agreed it should be eliminated as completely as possible. With regard to the desirability of keeping the naphthalene in the gas by means of oil sprays or injections of vapours, so far as his own researches on the matter had gone, he had yet to find an oil that would make a saturation vapour content of naphthalene in gas any higher than it was in ordinary gas; it produced no effect at all. Mis-statements had been made on that subject quite recently. There might be some improvement from the decomposition point of view. Referring to Mr. Goulden's remarks with regard to the increased illuminating effect derived from the presence of carbon monoxide, he believed the view as to the beneficial effect of carbon monoxide for lighting purposes was on a sound basis.

SECTION VII.—ELECTRICITY WORKS AND POWER TRANSMISSION.

Low Power-Factor.

At the opening meeting of this section the chair was taken by Mr. Ll. B. Atkinson in the unavoidable absence of the President of the Section, Sir John Snell, who was occupied at the London Electricity enquiry. After some preliminary remarks by Mr. Atkinson, Mr. R. O. Kapp read his paper, bearing the above title. The paper will be found reprinted on page 79 of this issue and we may at once deal with the discussion.

The Chairman was the first speaker. This question of power factor was, he said, undoubtedly becoming more serious than it had been. The devices for rectifying lagging current could be grouped under one or two headings. There was the condenser method, and there was the use of the synchronous motor, over-excited, which fed the leading current into the circuit and so balanced the lagging currents that were otherwise developed; then there was the oscillating system, which also was on the principle of injecting a leading current into the circuit. In addition there was the system in which a motor was run in one way or another generating an E.M.F. of a leading character. All these systems involved additional appliances which did not necessarily automatically adjust themselves to the amount of current that was being provided.

The greatest sinner was undoubtedly the asynchronous motor, as regards producing these out of phase or lagging currents, apart from the transformer, which was always there. One of the matters to which this country had not paid sufficient attention was the possibility of producing asynchronous or non-synchronous motors, which run with unity power factor at practically all loads. If they would consider an ordinary single phase, two phase or three phase motor having a closed circuit rotor, this, when running, took a leading current. If it were driven from a belt until its rotations were in phase exactly with the speed of the oscillations of the magnetic fields, it gave an E.M.F., but no current at all. If it were driven rather faster, it gave current as a generator which was a leading current. That was what they wanted to design, viz., a closed circuit rotor, to get that condition of affairs and giving motive power at the same time. The reason for what happened was that they were dealing with two magnetic fluxes; a flux which set up the transformer or inductive action, and a flux at right angles to it which set up a mechanical twisting moment, and these two, necessarily, in such a motor were equal. That was the reason why such a motor could not be run above synchronous speed. What was wanted was a motor with the commutator in two parts, in which the two fields or three fields as the case might be, need not be equal, so that the flux producing the current was not the same as the flux which produced the motive power. In that way it would be possible to run the motor below or above synchronous speed and with lagging or leading currents.

That type of motor had been developed to a considerable extent in the United States. Very largely they were the result of the efforts of Mr. V. A. Fynn, and the Wagner Motor Company had been supplying these motors, as had other companies. Very little, however, had been done over here in that direction and they were very little understood. He could not help feeling that Mr. Kapp's suggestion of giving a bonus to those who improved their power factor would give a great interest to the type of motor which worked at unity power factor and to a very large extent would enable the difficulty of the bad power factor to be got over.

Dr. S. P. Smith said low power factor was not a new problem. We had it with us years ago, but the problem was not seriously attacked perhaps because it had not reached sufficient economic importance. Low power factor was eventually paid for by the consumer either in the form of rectifying apparatus or in the form of tariffs, *i.e.*, if nothing was done to improve the power factor, the consumer would find that on the average he would have to pay more per unit for his energy. On the other hand, if the station authority put down rectifying apparatus, it was still the consumer who had to pay, and in the third case, if the consumer himself put down the apparatus, he also had to pay for it.

If there was a lower tariff rate, it was the consumer with the high power factor who was paying relatively too much and so helping the consumer with the low power factor. Therefore it was essential to make the consumer rectify his own power factor. There were several other points arising, also, in connection with which they ought to be very careful as engineers, otherwise they might introduce complications and trouble which would have very undesirable results. At present, many consumers who had induction motors were able to manage with unskilled labour for attending to them. It was very probable that in many cases, with many types of rectifying apparatus, they might compel consumers to use skilled attendance.

He was glad the chairman had called attention to the alternating-current commutator motor. There was no doubt whatever that as a motor, from the practical point of view, it was in every way inferior as a machine to the simple induction motor, but from the theoretical standpoint the alternating-current commutator motor was infinitely superior. It was possible to do almost anything one wished with the commutator motor. They could control the power factor and the speed, things which could not be done with the induction motor, or only at a certain expense and very often loss. He would rather like to emphasize that point because he believed the feeling against the alternating-current commutator motor was getting a little milder, perhaps because we were learning from experience that these motors could be built successfully, and we were further learning that speed control in any shape or form could not be had without paying for it. If it were possible at the same time to get conditions of high power factor, he believed the problem was well worth considering.

The other type of motor which seemed to be becoming rather popular and had a good future before it, was the synchronous induction motor which avoided the commutator. The method of working was to start the machine as an induction motor—the actual machine was an induction motor—and run it up to speed, then excite the rotor with continuous current and make it run at synchronous speed. It would be a unity power factor motor running at constant speed, and if that could be done, the problem would be solved very simply without the use of a commutator in any way. That was a line of development which ought to be encouraged.

Mr. W. R. Cooper could imagine, if he were a consumer, saying he did not want to spend money putting plant in, and certainly not rotary plant which wanted looking after. He would say he did not mind the supply authority putting in plant as long as it did not worry him and if they put in something which did not want looking after and did not take up much room. He thought that was rather a strong argument for the condenser.

Mr. S. E. Fedden said that when he first went to Sheffield they had a 5,000 kw. station which was practically a lighting station. After a few motors had been put on, however, they found the exciters were not big enough, so he wound extra exciter turns on the exciter coils and that helped things along for a while. Then came a few more motors and down went the power factor again and again he could not get the load out of the steam plant. He then bought a 750 kw. synchronous motor which he over-excited. That ran for many years and eased the situation. Before he got his new station going he found that he again could not get the load out, and the only way was to run a small turbine which he had, with just a whiff of steam into the steam end and over-excite that. In the meantime he stated in his schedule of tariffs to consumers that they must not put on any motors with less than 0·8 power factor. He then came up against the manufacturers because the manufacturers in the early days gave us motors which were very much worse than 0·8 power factor. However, after he had refused to connect a few they began to get some motors with slightly higher power factors.

The next step he had to take was in connection with his new turbine plant; he specified that the alternators should do their full load at 0·65 power factor, so that the most economical load on the steam end should be given when the alternator was being worked at 0·65 power factor. However, another transition stage came and he got some electric furnaces connected to the mains with the result that the 0·65 power factor jumped up to 0·8. The electric furnace was a wonderful rectifier of power factor up to a certain point, and he found that a lot of his machines were then too large. However, when there was a period of bad trade all over the City, when everybody was working short time, down went the power factor again, and he found that the precautions he had taken were then very useful.

The variation of power factor on a large system depended upon what was being connected. The greatest sinners of all were the rolling mills. Rolling mills could do pretty well what they liked, but the Department at Sheffield was taking the matter in hand and were going to make the rolling mills pay for their low power factor or rectify it. There was a case of which Mr. Selvey could give full particulars. He had been told to put it right and had made every endeavour to do so, otherwise his client was going to be made to pay for his low power factor by a fairly heavy charge for current. As the author had pointed out, it was very difficult to maintain the voltage right on low tension, when feeding through a transformer, and he felt that there would be a great advantage in the future by generating as near as possible to the main distribution voltage so that there would be only one transformation. He believed that the difficulties of low power factor would be very much increased with the superstation schemes where they generated at a fairly low voltage and then transformed up and transformed down for distribution and again before it reached the consumer.

Mr. W. M. Selvey said there were four aspects

of the question which different engineers might be inclined to lay stress upon in varying degrees. These were the technical question, the commercial question, the legal question and the psychological question. On the technical question, it was agreed that the apparatus to do anything that was required was available. Coming to the commercial question, they would find no measure of agreement at all. The thing had been debated keenly as between producer and consumer for 10 years, and in very few cases had any measure of agreement been come to. The author stated "Capital and running costs are generally much less than a bad power factor." If that statement could rigidly be maintained, then surely it placed the onus entirely on the supply authority because it was only necessary to instal the apparatus to save money for the undertaking and, consequently, for the consumer.

With regard to the case mentioned by Mr. Fedden, a rolling mill was a very bad example in the sense that it had to take big bites of load and then run light for long periods. That was an extravagant case, and could not be settled on the lines that Professor Smith had indicated, because the R.M.S. load on the motor was extremely low compared with the peak load, and, therefore, one could not afford to do as he was doing. If one started on a new design to meet similar circumstances, one would pay for a good deal more copper in the rotor and that definitely led to the next size, and, therefore, it was not quite so simple as Professor Smith had suggested. The two motors were radically different. The pure induction motor was a very much smaller and very much cheaper motor, but nevertheless, from the commercial standpoint, that type of motor would act.

This led him to the legal point of view which he was not competent to deal with. It was, however, very encouraging to find that the E.D.A. had taken the very important step of memorialising the Electricity Commissioners on the question of standardising tariffs on the K.V.A. basis. The suggestion of rebates had already, in effect, been put into practice by Mr. Fedden on his system, and it met the problem presented by the case referred to of the rolling mill, because there they were not dealing with the legal position, but with an agreement between parties. When there was an agreement that the power should be taken at a power factor of 0·8, and it was found the power factor was something very different, obviously the agreement had been broken. Thus the legal question in that case was a very simple one, but on the general question he believed it would have to be faced, and he believed it would be faced with tariffs on the lines the author put forward.

On the psychological question there was most to be said because what we had to-day was a state of things which had grown up, it might be said, from the implied contract. The implied contract was the method of contract which enabled a man to make any use he liked of the current and the only thing that bound him was his own personal interpretation of the word "similarly." Nobody has yet had the temerity to define the word "similarly," but they all felt they knew something of what it meant. If a certain condition arose from a contract, implied or specific, and it was found that the contract became onerous to one of the parties, it was a very delicate matter to say that he wished to cancel that contract and make a new one on an entirely different basis. That was where the psychological question came in, and the man who was to be hurt by the cancellation felt that somehow or other, when he was dealing with a thing he did not understand, and the other man wanted to make the change, that it was to the advantage of the other party.

Mr. C. P. Sparks said there were three aspects in which the matter might be considered, the station, the distribution and the consumer. From the power company point of view, the first two were involved, viz., the station and the distribution. The consumer was an independent undertaking, but it was easier to approach an answer to the question by considering the case where the station, the distribution and the consumer were in the same hands. It was difficult to get a true measure because under these conditions, as a rule, the operations were on a small scale compared with the normal conditions of a large municipality or a power company. Perhaps, however, he might give particulars of two undertakings in common ownership of a quite different character. The first was the case of power supply to an oil field, where the operating company owned the power station and the distribution and carried out the detailed working at the wells. There they were faced with operating a power factor of 0·5.

At first sight, one might say that such a power factor was so extraordinary that it was a thing that ought to be avoided, but owing to the nature of the working of the oil wells it was not very possible to see how any radical improvement could be made. When the wells were pumping, from 95 per cent. to 98 per cent. of the time they were running on, say, 5-h.p. to 10-h.p., but when they were pulling they had to develop a power of 30-h.p. to 50-h.p. The consequence was that the motors had to be of such a low continuous rating, as a proportion of their maximum rating, that the power factor was bound to be very low. Very great difficulties had been found in operation, particularly with regard to distribution, and some form of power factor correction was necessary. The ideal method was to correct at each individual motor, but owing to the comparatively small size of the motors that had not been found a convenient way of handling the problem. The way of getting over the difficulty had been to have a certain number of group points at which the power factor was corrected.

Another instance was in connection with mining on a large scale where the winding was by A.C. geared motors and there was a large proportion of haulage. Taking that type of motor it had also been found advantageous to go in for power factor correction. Here were two cases in which power factor correction had been found to be commercially advantageous, and if that be so in cases where all sections of the undertaking were in the hands of one person, it would appear that power factor correction as a commercial proposition should be adopted on a larger scale than was the case at present. The difficulty was one which had already been touched upon, and that was that the consumers, as a whole, were paying for it. That was an unfair thing because it was only a certain percentage of the consumers who were responsible for it, and he was entirely in agreement with the suggestion at the end of the paper that power factor should be taken into account in fixing the tariff.

He did not think, however, that it would be possible to have the very heavy penalties suggested in the paper. Neither did he think it would be possible to put in power factor correction to get very high power factors indeed. What he had in mind was that nobody would work very far away from 0·8. It might be possible to work up to 0·9, but working up to unity power factor was uncommercial. According to the figures worked out in the paper of the advantage to the consumer of improving his load factor, so far as the rebate was concerned, it was 5 per cent. on the tariff taken, or ¼ per cent. for every 1 per cent. improvement in power factor. If this bonus was offered it was probable that it would not result in a better load factor than 0·8 or 0·9, and for this power factor the actual amount received would be about 2½ per cent. on the tariff, and to get this 2½ per cent. it would be necessary to spend some money. It was an uncommonly difficult thing to get people to spend money where apparently the margin was so narrow, and he was rather of the opinion that it was up to the suppliers, if they could not tempt people by these tariffs, to themselves provide this special apparatus.

Mr. A. H. Dykes confessed that the only method he had used up to now was a rough and ready one due to the fact that in nearly every case where he was troubled with bad power factor it was a place where the charge was made under the blessed clause which enabled them to charge on any method they pleased so long as it was by agreement. A system he had found effective was to charge on the K.V.A. basis, using a maximum current indicator to measure the maximum K.V.A. and a running charge per unit. He had assumed in every case that the standard power factor was 0·8 because he agreed that it was not commercial to work at anything very much higher. There were some consumers who never would understand what low power factor meant. In that case, if they did not pretend to understand the technical side, they were quite willing to accept the ordinary basis. They did not appreciate whether it was K.V.A. or kilowatt, and, therefore, they paid on the maximum demand, and everybody was happy.

He had had very good results with condensers installed at the point where the power factor had to be remedied, the condensers were on the high tension side and the power was about 300 kw. There was no doubt that the proper place to have condensers, if they could, was on the consumer's premises, as although it was possible to improve the load factor on the station by over-exciting the motor alternators if they had them at the station, this did not help with the distribution. He had one case in mind particularly where he had to convert from three-phase 50 cycles to single-phase 70 cycles. By over-exciting the converters they improved the power factor at the station considerably, but they were very worried with the low power factor on the mains.

Another case he would like to mention was at Cambridge University, where they were taking supply for the University substation from the Cambridge Electric Supply Company, which was working single-phase. The company did not run its alternators or batteries in parallel and therefore would not allow the University to use a synchronous motor. Current was taken from the company and converted to direct current for the use of all the scientific departments of the University. Therefore they had to use a synchronous motor alternator and the power factor was worrying the supply people. Consequently, at the present time they were putting in at the University a 2,000-volt single-phase condenser for about 250 kw. That was also on the high tension side.

Mr. J. R. Blaikie, speaking with regard to an intermittently run power load, said that if it were charged on a low power factor basis and maximum demand, it simply meant that the plant at the station was hired by the quarter or the year. If, owing to the low power factor, the plant at the station was occupied by wattless current during the time it was running light, there should be no further charge. Low load factor consumers got no advantage from diversity and paid a penalty for their low load factor, although they contributed very largely to the diversity. In this way, he did not think they were any worse off than good load factor consumers who occupied the plant all the time. With regard to the method of making the charge, Mr. Kapp had suggested that the k.v.a. was not justified because it included the whole of the plant. That, of course, was true but it was quite easy to apply the load factor basis with a different scale of fixed charge, *i.e.*, consumers could be classified according to load factor, and a fixed charge arranged for each class.

At the recent discussion at the Institution of Electrical Engineers, some members seemed to find an anomaly in that system because two consumers having the same load factor would get their power at a different rate. He saw no difficulty about that; it came to the same thing as having certain adjustments, but it was much more practicable to keep the fixed price always analysed and up to date. In that form the electrical part could be charged at a higher rate than the mechanical part, so that adopting Mr. Kapp's figures, he believed it worked out that supposing the fixed charge was 5*l.* per kw., there would be an addition of about 5*s.* 8*d.* for each 10 per cent. stage in load factor. The apparatus required would simply be a maximum demand current meter.

Mr. Kapp, replying to the discussion, said the most important point that had been raised was whether it was worth while to improve the power factor above 0·8. The problem seemed to him to be of this order. A 0·8 power factor could be obtained with reasonably good motors, but to get a better power factor than that it was necessary to instal something in the nature of condensers, or static or running plant. Some time ago he got from some manufacturers of phase-advancers some figures for comparative purposes and found that according to

the circumstances the cost varied very much, but it seemed to come between 1*l.* 10*s.* and 2*l.* 10*s.* per kw. of the motor in order to improve the power factor from about 0·8 to about 0·95. It also seemed that it cost a great deal to get the extra 0·5 per cent. from 0·95 to unity. In the paper it was stated that the cost of bad power factor was 3*l.* 8*s.* in the example given so that the cost of bad power factor was very much more per kw. than the cost of power factor improving apparatus. If also account was taken of the fact that the plant installed was a great deal more than the kws. of maximum demand it seemed probable that it would pay to instal devices which improved the power factor beyond 0·8. Various speakers had said they found it pay to instal condensers. The objection to the proposal of Mr. Blaikie to charge on the k.v.a. of the maximum demand was that the consumer did not so readily see that he could reduce his bill by improving his power factor.

SECTION I.—RAILWAYS, ROADS, &c.

ON Thursday, June 30, Section I of the Engineering Conference met at 10 a.m., again under the chairmanship of Mr. W. B. Worthington. The adjourned discussion of Mr. Drury's paper on "Tunnel Maintenance" (see page 30 *ante*) was first taken.

TUNNEL MAINTENANCE.

The first speaker at this meeting was Mr. E. F. C. Trench, who agreed that maintenance on some tunnels was very costly, while on others it was negligible. On the railway he served there were 46 miles of tunnels; on many of these there was very little to do, while in others work had been necessary exceeding the original cost of the tunnel. The faults in the old tunnels were seldom faults of design, and most had proved to be of ample strength. He was not speaking of special cases of tunnels subject to subsidence by mining, &c. One of the chief defects he had encountered was that of workmanship, especially the filling of cavities behind the brickwork and the use of unsuitable materials. Brickwork which remained sound in the open very often failed in tunnels due to the deterioration of the mortar. The presence of sulphurous and other fumes due to bad ventilation also caused trouble. In one of his old tunnels, 1½ miles long, the brickwork failed so that the inside ring of brickwork had to be removed and replaced by blue brick in cement, tied into the old work by three headers to the square yard. The lines were pulled in towards each other and the arch built on a travelling centre of sufficient length to support work for a week. The work cut out was piled on it and removed at the end of each week. That work, not a particularly difficult case, cost 20*l.* per yard, which showed how costly an error in the selection of material might prove. The cement gun should be used with caution. It might do for small cavities, but could not be used for large. In tunnel building the maintenance of the railway should be kept in view, and proper provision should be made for water encountered, and for ventilation. In many cases rails in tunnels had to be renewed three times as often as those outside. That might be reduced if more attention were paid to dealing with the water and to ventilation. The latter might be improved by having more shafts. Engineers in the past had usually erred in the direction of making the ring stronger than necessary. Cavities were a difficult question. It was often difficult to get crown bars taken out. Special arrangements, with special payment, should be included in contracts, for this work.

Mr. H. H. Dalrymple-Hay said that a little while ago he had seen an old canal tunnel which was unlined. In 1917 there had been a fall for about 25 ft. by 9 ft. in width and 6 to 7 ft. thick. The tunnel was 120 years old and was a good example of what might be done in hard chalk. In order to understand tunnel failures it was necessary to have a knowledge of the ground and an intimate knowledge of the work done during construction. The latter was impossible with tunnels 80 years old, as many were. In tunnels in chalk he thought failures occurred owing to filling on the outside being lacking. In the Oxted tunnel the late Sir James Ball had decided to rip out the old and build sections of new brickwork. More recently Mr. Drury had decided that that was not quite necessary and had adopted filling outside instead. The cavity outside had been the cause of the failure. He considered Mr. Drury correct. No calculations of tunnels were worth two-pence. It was necessary to rely on decent inspection and then hope for the best. If Mr. Drury made holes in his tunnels which had not failed he would also find cavities. Part of the Betchworth tunnel had been built in dry sand devoid of all cohesion. Under those conditions, with unsymmetrical weight there was sure to be failure. With any opening of the joints dry sand ran out in a stream, and the bricks having crushed, the tunnel changed its shape and fell in. In the Betchworth tunnel Sir John Fowler had ripped out the lining and put in a complete section with an invert for a length of 55 yards. At the north end of the tunnel in greensand they took out the side walls and left the arch standing, building under it a relieving arch and packing the space between. That made a sound job. To-day, in tube railways near to buildings everything was grouted. That was not thought of in the old days. In clay he thought tunnels should approach the circular form. Clay was not homogeneous, but was jointed in all directions. When disturbed by tunnelling, water came down, and due to expansion the clay would exert tremendous pressure on the tunnel.

Mr. A. Stewart Buckle said the Betchworth tunnel fell in in 1888. The sand at the point of failure ran as in an hour glass. Sir John Fowler was considered to be excessively cautious in his treatment of the failure as the tunnel was by no means all bad.

The chairman said that miles of tunnels that he had had to do with had required constant repair on account of careless work behind the tunnel work.

Mr. Drury, in reply, said he had had no failures from bad bricks. Although there were soft bricks there had been no sign of crushing due to defective material. One cause of failure was due to rocks or chalk falling and bursting through; the chief cause was erosion on the face ring. Even Staffordshire brindles in cement were not a complete cure for this. With the cement gun using grit with plenty of water the joints could be cut out to a depth of ¾ in., and when putting on the skin with 40 lb. pressure these were filled up with very dense cement. The whole surface was afterwards coated with ¼ in. of cement which held very well. Even if it did come away it was cheap to replace, and it protected the work behind. No money was lost by grouting instead of packing on spaces up to 4½ in., while there was a gain in speed. The cost was about 7*l.* per yard. Grouting made the haunches absolutely sound. It also assisted in localising water and made the lining impervious.

THE USE OF REINFORCED CONCRETE ON RAILWAYS.

The next paper to be taken was by Mr. W. W. Grierson, on "The Use of Reinforced Concrete on Railways." This paper we reproduce on page 79. The first speaker in the discussion was Mr. W. Marriott, who said he had put up concrete bridges for forty years. One he remembered, put up before his time, was ugly and contained bad work, but it had stood. Mr. McDonald, when engineer of the Midland Railway had criticised some of his bridges, saying that with girders buried in concrete no one could tell what was going on. In reply a section was opened up and the reinforcement was found quite clean and free from rust. On a line connecting to another line his bridges were built of concrete except over the connecting line where the other company had insisted on brick. In eight years the latter had to be replaced. Concrete was used and had stood to the present day. Much could be learnt from French and Italian engineers, who had gone further in the use of reinforced concrete than we had. Much of the reinforcing abroad was, however, carelessly done and was exposed. That might do in a dry climate, but would not do here. Little points like the washing of granite aggregate wanted attention. He had considerably reduced his staff by using reinforced concrete for nearly everything for which it was suitable. It was often used for unsuitable purposes, and failure naturally resulted.

Mr. B. L. Hurst thought engineers had been rather too conservative with regard to reinforced concrete. Unfortunately, reinforced concrete needed much more careful designing than timbering, masonry, or steelwork, and more careful choice of materials and careful work. It also needed a period of quietness and freedom from shock which was difficult to ensure on our railways. For piles it had advantages and a given load could be carried cheaper on such piles than on timber. For retaining walls it also had great advantages. In reinforced concrete it was essential to provide full adhesion lengths for all rods. With that and end-hooking and ample hooping there need be no fear of disintegration. Where the ratio of total load to dead load was high mechanically-bonded bars with frequent projections should be used. There was not much economy in reinforced concrete girder bridges unless it was possible to place the girders under the slab. The time taken to place the reinforcement, and for setting, made this class of work hopeless for reconstruction. That might be partly got over by pre-cast work. With reference to foot-bridges he thought it would pay to make centreing which could be moved quickly from one place to another. Buildings built on this principle were really fire-resisting and not dangerous like the so-called fire-resisting steel building. Mention might be made too of the use of reinforced concrete for roads for heavy traffic. Such roads had been laid down to a very large extent in the United States.

Mr. H. H. Allott said the Manchester Ship Canal Company had constructed a bridge of 30-ft. span of reinforced concrete. It weighed 54½ tons and was built alongside the line and lifted into place, the actual placing being completed in 24 hours. In one instance where the engineer of the company had to take a railway under a main road with very little headroom, he had used pre-cast reinforced slabs, 15 in. deep at the centre and 27 in. deep at the haunches and 4 ft. wide. Each weighed 6½ tons. He had himself used reinforced concrete for viaducts at collieries and found that that material withstood impact satisfactorily. He agreed that unless the girders could be placed under the road there was little economy in the use of concrete for bridge work.

The next speaker, Mr. W. Willox, stated that he had used reinforced concrete for bridge work in 1910 for the King's Cross Bridge of two spans over the railway and platforms, the spans being 50 ft. and 27 ft. respectively and 60 ft. wide. He hardly liked to state the difference in cost compared with a steel structure, but it was about one-fifth. A 40-ft. span bridge he had put up at Harrow had stood satisfactorily. It was for shunting on a five-chain curve. At Baker Street the offices had been erected of the same material. A retaining wall there was 20 ft. deep and only 6 in. thick, backed by horizontal concrete girders forming part of the building and two sets of struts. He had recently put up an armature shop 120 ft. by 60 ft., with two spans and a great deal of glass. The locomotive engineer was enthusiastic in favour of concrete for such a purpose. It was essential that reinforced work should be properly inspected. Its adoption resulted in saving in weight. It cost practically nothing for maintenance.

Mr. E. H. Morris said he had used reinforced concrete for mound walls. In section these were L-shaped with the foot turned inwards and loaded with the filling. The wall itself consisted of grooved verticals cast with the foot slabs, thin vertical slabs being placed in the grooves. A small coping covered the top. The height was 4 ft., and the present cost about 4*l.* per yard, or about the pre-war cost of a brick mound wall. The coping could be formed with a ridge underneath at the back to prevent it slipping forward, and could be notched on the upper side at the back to take the thickness of flags or planking, thus preventing settlement. That could not be done in ashlar except at great cost.

Mr. H. W. FitzSimons said that Mr. Grierson seemed to imply that strength was largely due to richness, and that sand was the most important part so far as filling the voids went. Reinforced concrete work was really a matter of money. Messrs. Taylor and Thompson in their book "Concrete, Plain and Reinforced," gave particulars of a method of mechanical analysis of the aggregate by which the best practical grading of the materials could almost

be settled in the office. In one case by its use the density had been increased from 145 lb. to 149 lb. per cubic foot and the compression strength increased 25 per cent.

Mr. H. Jackson said if one-hundredth part of the attention which had been devoted to the structure of steel had been given to concrete the same improvement would have been achieved. If the dirt which had no adhesive power at all was washed out of the aggregate the strength of concrete would be increased 5 to 10 times. Reinforced concrete was wonderfully adaptable for work below ground. He had used it for inverted retaining walls with excellent effect. He had distributed his load over a large foundation and had turned the sides down all round to form an inverted retaining wall which he had built to take the side pressure from the load in the centre, the wall being built in a trench just wide enough to get a spade in.

Mr. R. Pawley instanced one of the disadvantages of concrete piles. In the case of 50-ft. piles for a large warehouse trial piles had been driven for the purpose of estimating the length. When actual driving commenced the ground was so compressed at the groups that the piles could not be driven right down, 10 ft. to 12 ft. standing up which had to be cut off. This cutting made the reinforced piles come out very expensive, more so than the cost of timber piling.

Mr. R. J. Money said before the war he had tried to find out what happened to reinforced concrete in hot countries, as he had to consider its use for Mesopotamia. He secured very little information, but in Cairo, though used for foundations, he found that several large structures above ground had failed. In the case of a river wall along the Nile he found that at the point of failure no bars had sheared, but all had pulled out of the concrete. The sections left standing all sounded hollow on tapping and he concluded the concrete had no hold on the bars, possibly because the latter may have been at a very high temperature, 140 deg. to 150 deg., when the work was done.

Mr. W. Higham said his experience of this material in large buildings in Singapore and Penang had been most satisfactory. There had been no failure except in one case in which the work was badly carried out. He did not think temperature affected the matter much.

Mr. R. P. Mears said that in tropical countries the temperature of the bars could always be got over by adequate watering. If that were done the structure should be perfectly safe. In Bombay and other parts of India reinforced concrete was more used than in England or the Continent. The failures were due to want of precautions. Timber plugs should not, for instance, be inserted unless wired round or enclosed in a piece of pipe. Water two or three inches deep should be kept on slab work for a fortnight by means of a bund, and even after that slabs should be watered. Work done in the rains was better than that executed in the dry season. Small tanks were particularly successful. Railway sleepers at terminal stations, where the speeds were low, were a success because the trouble due to frequent replacements was eliminated. He thought slabs might replace much of the ordinary troughing in English bridges with advantage. Troughing was expensive and troublesome in upkeep and the adoption of slabs would not upset the ordinary designs.

Mr. W. W. Grierson, in concluding the discussion instanced the case of a retaining wall on the Great Western Railway, between two sets of lines at different levels leading to a coal tip. The saving in space by the use of a reinforced retaining wall a few inches thick had been very valuable. It had been built on a slab foundation with good results. Several bridges had been built near their sites and lifted into position. He thought there was little economy over steel bridges by this method. The cost of maintenance he thought was probably less if the work were well done in the first place. He had had cases such as Mr. Pawley had referred to and some expense was necessarily incurred in such instances.

IMPACT TESTS AND ALLOWANCES.

This subject was introduced by Mr. H. J. Fereday, whose note is reproduced on page 80 of this issue. The discussion was opened by Mr. C. J. Brown, who said there were great difficulties in analysing the records of tests of impact on bridge structures, when they were secured. The chief component, and the most difficult to ascertain was due to the unbalanced weight of the locomotive. There were so many types of bridges and of locomotives that thousands of tests would be necessary to reveal the real state of affairs. Mr. Fereday suggested tests with electric or four-cylinder locomotives. The question of impact due to electric locomotives had been fully gone into by American engineers and was discussed in Bulletin No. 204 of 1919, of the American Engineering Association. That report considered the impact due to electric locomotives to be about one-third that due to steam locomotives, which would result in a big reduction in the stress. The tests referred to the longer spans and did not apply to anything less than 25 ft. Indian engineers had looked into the question, but not with altogether reliable results. Locomotive engineers could reproduce in their shops the running conditions, and ought to be able to give valuable information as to the effect of variations in the balancing of a locomotive at high speed. He regretted that Mr. Fereday had not included in his paper some of the results obtained with his instrument. The subject had been gone into in America and India, and in this country by the Ministry of Transport. The old Pencoyd formula $\left(I = \frac{300}{300 + L}\right)$ gave a curve for the percentage of increase of live load stresses to allow for impact effect which fell slightly with increase of span. The American Railway Engineering Association formula $\left(I = \frac{30{,}000}{30{,}000 + L^2} \text{ or } \frac{300}{300 + \frac{L^2}{300}}\right)$ gave a curve whose values decreased less rapidly than the Pencoyd curve to start with, but rather more rapidly at the longer spans, the curve at first remaining above the Pencoyd curve and then crossing below it. The Ministry of Transport had two formulæ ($I = \frac{120}{90\ L}$ for single line, and $\frac{120}{90 + 1\frac{1}{2}\ L}$ for double lines). These gave curves of values above those previously cited with short spans up to about 30 ft., and falling to considerably lower values for the longer spans. The effect of the unbalanced weight of the locomotive was dependent upon the wheel diameter and speed. It set up a certain impulse on the bridge. The bridge itself had a natural period of vibration. If these coincided the worst impact effect resulted. On long spans the critical period was low and possibly the maximum impact effect was frequently reached. On short bridges and cross-girders it would be much higher.

Mr. C. Gribble said impact tests should be considered part of a much larger investigation. He did not think that engineers really knew what the static stresses in a bridge were. The impact formulæ gave a percentage increase on the static stresses which it was therefore important to know. In all tests that had been made recently with stress recorders he believed the static stress recorded was much less than the calculated stress, due to assumptions to cover inadequacy of knowledge. The factors of safety introduced resulted in the actual stress being less than the calculated stress, sometimes by 50 per cent. If one took a proportion between the static and impact stresses and merely added that to the calculated stress one might be adding useless material. The importance of the matter was less to the designer whose allowances might involve some increase of cost, than to the maintenance engineer who had to decide whether or not the bridge had to come out and be replaced. The differences between the formulæ were of great importance in this connection. He did not think the formulæ should plot impact values to span. It had never been ascertained that impact had any scientific relation to span. The empirical formulæ had a certain value in giving a margin over the static stress, but he doubted whether they were to be considered accurate. Future experiments would have to be much more scientific and the analysis thorough. The American experiments were well carried out but badly analysed.

The discussion was then adjourned till the morning of Friday the 1st inst., and its continuation will be given in our issue of next week.

SECTION III.—MACHINERY.

At the meeting of this section on Thursday, June 30, the chair was occupied by Sir William H. Ellis, G.B.E., who called on Mr. A. H. Hall to read his paper on "The Influence of the Automatic and Semi-automatic Machine on the Skill and Resourcefulness of the Mechanic and Operator." This paper we print on page 80. The Chairman, on declaring the paper open for discussion, said that he would himself say a few words later on.

THE SKILLED CRAFTSMAN AND THE AUTOMATIC.

The first speaker was Captain J. E. Mortimer, who said that during the war Mr. Hall was in charge of the Submarine Mining Production Department of the Admiralty and was one of the few successes obtained from outside. Under his direction articles were produced when they were wanted in face of constantly fluctuating demands. A contributory factor to his success was the excellent co-operation which existed between him and the employers; and similar co-operation was necessary between employers and workmen if full benefit was to be obtained from automatic and semi-automatic machines. Mechanics commonly regarded them as "job killers," because they did not realise that cheaper production meant increased sales. There was this to be said on their behalf, that they had not always had a fair share of the extra profits made by the use of automatic machines. There was plenty of initiative to be found if every employee in the works benefited by improved results. Such a system was now at work in many engineering shops in absolute harmony with the local trade union. In consequence, the automatic and semi-automatic machines were no longer a bugbear. As showing the spirit prevailing in these shops, he mentioned an instance where a fitter thought a riveter was getting on a bit too slowly, and said, "Let me give you a hand on this, and we will get a share of the profits." In such cases the men acted as their own policemen, and if they found a loafer in their squad they passed the word along, and said they could do without Bill. The office staff thus dropped more into their true functions of giving assistance rather than giving orders. It was particularly in regard to the different qualities of material that the information supplied from the office should be ample. Close co-ordination was necessary between the office and the workshop. It was believed that that could only be secured by arranging that the office staff engaged on this part of the work, and the mechanics who set up the machines, should change round occasionally. Messrs. Alfred Herbert sent out fully qualified engineers who not only could explain their machines to the workmen, but could take hold of a job and put it through to show what could be done in a certain time. The resource of the mechanic was not always destroyed by office instructions. In fact, these often spurred him to devise methods to show how much better he could do the work.

Mr. Hall had claimed that it was in the small shop that the highest degree of initiative was displayed, but in the speaker's opinion still more was needed at sea, where it was impossible to walk across the road and get another piece of material. There was no doubt that the more automatic a machine became the less need was there for initiative on the part of the operator, but such a degree of specialisation implied great study and very great accuracy on the part of the designer, so that the initiative was merely transferred elsewhere. As to whether long experience was valuable, the speaker's observation was that long experience was a poor qualification in a mechanic, unless flexibility of mind and progress were included. The skill displayed by women on automatic machines could not be said to be greater than that of men. They were undoubtedly more patient, and were more satisfied with the conditions than the average man would be. That women were generally more skilful with their fingers was no doubt true, but there was a difference between skill and keen sense of touch, and the women scored generally in quickness rather than in this. A woman was generally less responsive to altered conditions than a man, and in consequence would spoil more work when engaged to work on material to which she was not accustomed. When she did learn she might be

more responsive, and ultimately might produce a smaller percentage of wasters. He had had rather an interesting experience in that respect. There was one woman who wanted to do automatic machine work, and by her wish she was allowed simply to sit and watch the operator. She sat there for three weeks solidly, and watched the whole time. Then she started, and in about two days she was as good as the operator. The effect of the automatic on the initiative of the mechanic must finally be largely dependent on the initiative of the management. By sheer atrophy of the brain an intelligent mechanic might be reduced to a semi-automatic man. It was reasonable to assume that at least half an hour a week was lost by each mechanic in reading instructions, or having them explained. There were plenty of works where it would pay to have operation films that could be run off rapidly, as operations could thus be seen, and understood in far less time than they could be read.

The Chairman, who spoke next, said there was one point which stood out prominently in Mr. Hall's paper, namely, that the success of the automatic machine was largely influenced not only by the skill of the mechanic in accurately setting up the tools, but by other circumstances. He might set up the tools absolutely accurately so as to be beyond criticism, but if the material which had been supplied for those tools was not as accurate in quality and in hardness as his work was accurate in setting, his work would be a failure. The manufacture and production of high quality tool steel of even hardness and extreme uniformity was certainly a fine art. He would say that at least half the trouble and half the complaints they had on the subject of tool steel were brought about by users failing to realise the importance of never treating or dealing with a tool in any way which would possibly alter its temper. One found in important works in this country that firms would pay for nickel chrome or vanadium steel three or four times as much as they would pay for ordinary carbon tool steel. These firms seemed to believe that, having paid that price, they could do what they liked with the steel. A piece of tool steel which contained nickel, or chrome, or other costly alloys was, however, no better than the ordinary steel if it were not treated so as to bring out its special virtues. Indeed, the presence of chromium in a steel was a danger unless the steel was properly treated, and tools of any alloy steel which were received in the finished condition from the makers should receive no further heat treatment. He would add that no expense within reasonable bounds was too great which would give uniformity of hardness and increased length of wear in the case of steel to be used for automatic machines.

Mr. F. E. Robinson said that his experience had been that the best tool setters for automatics had been men who were trained as tool makers. He also had found some of the best foremen he had ever had were men who had had considerable experience on automatics. As regarded the skill required for the setting up of capstans, he had found that men of rather special temperament were wanted, and one frequently got far better results by attempting dilution, as was done during the war, and selecting men who had had considerable experience in actually operating capstans. Regarding the skill displayed by women, his experience was that women had been an absolute failure, and an expensive failure, in supervising automatics. One had nearly always to put one woman to watch each automatic. She did not like the dirty work or the oil with which most automatics were smothered. He had found it very much better and much cheaper to have a system of a mechanic and an operator together supervising automatics, the operator being engaged in watching and feeding the bars into the machine, while the mechanic did the skilled work. Reference has been made to the quality of material. His experience had been that there was not much wrong with the treatment of the tools, but the trouble lay in the bad bar materials supplied. During the last fortnight he had had occasion to analyse some brass material, which was, perhaps, a war relic, but he found the variation in 60—40 brass ranged from something like 65 per cent. copper to very nearly 55 per cent. copper, and the lead content varied very considerably. That brought him to the point that in future in his own department he was afraid he would have to specify a very much closer analysis and a very definite lead content if they were going to maintain the quality of their machines; and also maintain, not only the quality, but also accuracy in limits. The influence of material on the limits produced was very great indeed. Another point which influenced automatics more than the question of tool steel, was the question of lubricants. He had attempted to use soluble oil on automatics instead of ordinary oil, but the tools had to be sharpened three times as often. As regards the economic question he had found that if there were a moderate number to do, say, perhaps 2,000 or 3,000 of an article, it paid to use a mechanic who was a skilled man and an operator who was an unskilled man, or a semi-skilled man, even for two automatics only, that was to say, if a man only ran two batteries he could compete with the capstan, and turn out work as cheaply.

Mr. Peel said he had come to the meeting under a misunderstanding, but he would like to say one or two words of a personal nature with regard to the author of the paper. During the war it was his duty to act as a sort of liaison representative between his firm, who were manufacturing various forms of electrical and mechanical gear for Government departments and Government offices. His experience was very interesting indeed. He found in many cases that the people he had to deal with in Government departments had been put in because they wanted somebody to fill a job, their knowledge of it was very elementary indeed. In one instance, having to build certain gear, some special wood screws were required, which his firm could not get, and wished accordingly to make them on their automatics, but could not get the steel without a permit. There was great difficulty in getting a permit for the steel, so eventually he went to the Department of the Ministry of Munitions and saw the official there. He explained the difficulty, and asked him for a permit for the steel. His answer was: "Don't talk nonsense; don't you know they are wood screws?" After that experience, he came across Mr. Hall's department, and it was a revelation of efficiency to him. Mr. Hall knew where everything could be got, and its price, and if they were in a hole for any material, he got it for them, doing in fact, things which were almost impossible. The gear they were building for that department was of a very confidential nature—in fact, so confidential, that he thought it was confidential to this day. After they had built part of this apparatus, it had to be tested by Government inspectors who were very capable men, but they had no idea as to what the gear was to be used for, and very naturally they tested it in the wrong way. His firm were in the same condition of ignorance and they had rejection after rejection. Finally, he went and saw Mr. Hall, and explained the difficulty.

Mr. Hall, in confidence gave him the general idea of the scheme, and at the same time informed him that a certain piece of apparatus ought to be used in the testing of it. He thereupon applied to the department, which said it was quite impossible for this apparatus to be handed over to anybody as it was most confidential. Back again he went to Mr. Hall, and stated the difficulty. Mr. Hall calmly said: "Stuff and nonsense; there is nothing confidential about it at all. Come up to my office at 12 o'clock and you shall have one." He went back to Mr. Hall at 12 o'clock and they had that apparatus, which for precaution, though there was nothing confidential about it, was sealed up in a box; and then all the tests went through perfectly. He did not feel competent to offer any criticism of Mr. Hall's paper, but there was one point which he would like to mention, and that was Mr. Hall's use of the word "mechanic." They had rather got into the habit during the war of taking absolutely unskilled labour, putting it on to automatic machines, and calling that man a mechanic; but he was not a mechanic, or anything approaching it—most probably a fortnight before he had been tilling the soil. His firm did not use many automatics because they were not engaged in general repetition work. Hence they kept their automatics running very largely on screws and nuts, not altogether for the sake of cheapness, but because they were thus certain of supplies; also if any special orders came in, by a very slight adjustment of the automatic machine, instead of having to wait weeks, they could, perhaps rather expensively and inefficiently, get the stuff they wanted, and that paid in the end. With regard to setters up, he found, as Mr. Hall suggested, that they were really born and not made. One or two of their setters up were men who could not even be called mechanics. If one put them on to a lathe or bench they would be hopeless failures, but they had that extraordinary intuition by which they could set up an automatic machine very much finer and in very much quicker time than a man who was really a skilled mechanic.

Another point he would like to mention was in connection with women's labour. They had never used any woman on lathe work or automatic work; but on general work they had used a large number during the war. Their experience was if they took a woman and told her exactly what she had to do, and had a foreman looking after her showing her the operations piece by piece, he telling her what a hammer was and what a screw-driver was, and how to use them, and then let her start; after a time she would be very quick and apt. Then, when she had made several hundreds of one article, and she was given another piece of apparatus of a similar type, using the same hammers and the same screw-drivers, and so on, she was absolutely at sea, and one had to begin educating her all over again. That was their experience with the ordinary untrained labour they got, namely, the girl who had been a domestic servant, or a shop girl; but it was entirely different when one had more educated women. They had a squad of officials' wives, bank managers' wives, and various squires' wives from the neighbouring country, who came in and put in about six hours a day simply for patriotism's sake. They did most extraordinarily well. One could turn them from one job to another, and with very little showing their superior training immediately came out. In fact, they kept them in a squad by themselves more or less, because one knew one could push them from one part of the shop to the other, depending on what jobs they had in hand. Somebody said that girls were not very handy with their fingers. They had not found that this was so with instrument work. They had employed girls on fine instrument work for many years, and they were infinitely superior to men. They had a much finer touch, and they could carry out all the adjustments necessary in moving instruments with a greater degree of accuracy than the ordinary man.

Mr. H. A. Acland said that during the war his firm were one of the few in the country where they found that girls on a hexagon turret capstan lathe could, and did, set up very well indeed. The girls themselves had been operators, and they chose the most intelligent operators. Eventually they worked up till they displaced the men. They were unable with the big batch of these machines they had—they had 375 in a row doing the same work—to obtain sufficient skilled men and had to start with unskilled. They were obtained in London, and trained specially on these machines at the Polytechnic and did remarkably well, but they discovered girls could do even better. The men's teachers were not very pleased, and to satisfy them that the girls were better, a test was made. A girl who was a setter of a fortnight's experience and one of these men who had been on these machines six months were put on to similar machines, both stripped completely at four o'clock in the afternoon, and told to bring to him the first head which passed Government inspection. The operation was making a 60-lb. shell head. The girl brought it at 6.30, and the man went home at 8 o'clock, having failed to do it.

Mr. Tripp said that as to the question of detailing operations in the office, this was the only place it could be done scientifically and properly, but it was also essential to have real co-operation between everyone in the factory. They often heard of a case where a machine-setter brought forward a suggestion, and he was told it was not his job, but a man

in the office was doing the work. That was practically asking him to submit to a soul-deadening sort of existence. If one had all the work laid out in the office and detailed in every respect, and then submitted to the shops for their approval before it went out into the factory, very good suggestions might be made and the whole operation modified. With regard to women on automatic and semi-automatic machines, he was entirely in agreement with the remarks of Captain Mortimer. They found that women were remarkably good so long as they stuck to one operation; whereas, if one put young men on similar work they would be pestering one all the time to get on to a higher class of work. The woman was satisfied to go on excelling in actual production, which was what one wanted during the war. There was one point which had not been touched on, and that was whether it was advisable in any circumstances to put a fully-trained mechanic on the working of semi-automatic machines and turret lathes. One or two firms suggested that one got a higher output and bigger return for one's outlay by acting thus; but, personally, he was not at all satisfied that that was so, and he would very much like to hear the results of Mr. Hall's experience on that question.

Mr. E. W. Monkhouse said that, however well a machine was set up, if the man did not work the machine properly, and had not the proper touch, he was no good at all, and would turn out a tremendous number of wasters.

Mr. Hall, replying, said that it appeared from what most of the various speakers had said that the question of women's labour was one on which there was a very great diversity of opinion. The remarks he was going to make might be somewhat theoretical, but the paper was half psychological and half engineering, and such speculations were profitable on many occasions. If the woman was regarded purely as a machine doing a certain amount of work, she was very much more inefficient than a man. A woman at rest took (he was speaking of average figures, and individuals would vary) about 60 calories per hour to keep the function of life going; on the other hand, a man would take about 100 calories per hour. When one came to the maximum amount of effort that a woman could achieve as compared with a man, one found that on an average her maximum effort was measured by an expenditure of heat of about 125 calories per hour; whereas a man's was 450, and a woman as an engine required four-fifths of the fuel that a man did. The inference of the argument was that if a woman could turn out on capstan lathe work as much as a man, the man was only working at less than half load; and secondly, it was obviously a job for a very young boy if one were not going to use women's labour. That was an interesting sidelight on the matter, but where physical exhaustion was the great factor, the woman did not compete with the man. His experience, like that of some of the speakers, but not of others, was that the question of touch in a woman was most important. The fact that she would be content to work on one operation where a man wanted variety, at any rate where production in large quantities was required, was quite a point of importance to the works, for a woman became extremely expert on a fixed job.

Captain Mortimer and Mr. Tripp, in dealing with the question whether the operations in production should be detailed in the office or in the works, had urged the necessity for co-operation between the office and the works. That was a truism, but if the work was detailed in the office, there was a tendency for the man in the office to theorise. If he did not keep in constant touch with the works, he began to get frightened of the works, and theoretical considerations weighed with him more than practical considerations. The ideal method was where, in the first place, the works were asked in what time they could do a given operation. He had known cases of particularly successful works of moderate size where, when a new piece was undertaken, it was sent down to the foreman who was asked to send up half-a-dozen pieces, giving the time. Those were then gone into by the expert in the office. By starting in that way, co-operation with the works was ensured.

Dealing with the points of the various speakers in more detail, Captain Mortimer mentioned that he considered long experience was a poor quality in a mechanic, and that initiative was far more important. This resolved itself more or less into the view that the main factor in a successful mechanic dealing with an automatic machine, was his imagination. Experience did not increase imagination, and if his experience were not of the right class, it might very likely dull it. Sir William Ellis made some very interesting general remarks, and then went on to talk about the importance of the material being right. There was one practical point with regard to that, that was not always appreciated. They might take, for example, the turning of a pulley. It was put on the turret lathe, and one wanted to turn the outside and bore it at the same time. If one were not using steel of the very best quality one was limited by the speed at which the surface of the pulley could be turned, and the drill would be drilling at far too low a speed. With steel of the highest quality which could be depended upon, the turning speed could be increased, and the drill would give the maximum efficiency. He did not think it was always realised what a very low percentage some of the automatics gave in the matter of efficiency. In one case it was determined as there were over a million of a certain article required it would pay to put it on a four-spindle automatic. The time of production was worked out very carefully, and it was found that from 38 to 40 could be obtained per hour. The article was steel, and it involved rather a heavy drilling operation. Forty per hour on a four-spindle automatic machine was a good production, and the work went on. When the running time came to be examined and worked out, it was found that the efficiency of the machine was barely 35 per cent. The time taken to set up the tools and grind them, &c., completely nullified any advantage that could be obtained by using a machine which, on the face of it, looked the best machines. It was finally decided to split the operations, and do the first part on an automatic machine, re-chuck, and do the boring on a capstan lathe. He could not give the actual efficiency, but he believed that output was nearly doubled at about the same cost. Where shops were allowed to do the whole of their setting-up they were apt to lose sight of such considerations. The variation in material as having an effect on the way articles gauged was interesting, and he wondered, in view of the very large amount of war material that had become available for commercial use, whether the admixture of cartridge brass, the composition of which was not too accurate during the war, was definitely deteriorating the class of rod which was going into automatics at the present time. Mr. Acland found that girls could set up machines better than men, but he probably was dealing with special cases rather than average cases, though it was interesting to hear that he had achieved success with the women.

Mr. Tripp had requested his opinion with regard to the use of mechanics on tool lathes. In all ordinary work he could not see that a mechanic was called for actually to operate the machines; his experience was rather required on very hard material and somewhat intricate work where the accuracy required was greater than that possible to attain in ordinary commercial work. It would probably pay to use mechanics under those conditions. Mr. Monkhouse referred to the necessity of a man's being able to work the machine, and the number of wasters which were turned out. It was rather surprising, considering the semi-skilled nature of the work so far as the capstan lathe was concerned, how much out of truth the work could be turned out by putting an inexpert operator on.

MECHANICAL APPLIANCES AT DOCKS.

The chair was then taken by Sir A. T. Dawson, who called on Mr. Musker to read his paper on "Mechanical Appliances and Labour in Loading and Unloading Ships' Cargoes." This paper is printed on page 81 of this issue. In opening the discussion, the Chairman said that the subject was of very great importance to all traders and to all engineers. The note was rather sad reading, because it showed that they were by no means up to date. He personally was associated with a big line of steamers in Canada which carried a very large amount of coal and iron ore. He had made a short note from some information which was brought before him in connection with an American steamer, the "Emory L. Ford," which arrived at Duluth at midnight on November 28, 1920, with a cargo of 13,589 nett tons of soft coal. That coal was removed to the dock, and the ship sailed at 3.45 p.m. on November 29, so that the coal was discharged at the rate of approximately 1,000 tons per hour. In 15 hours this enormous quantity of coal was put on to the dock, and the ship sailed. The average loading time for coal on the Canadian great lakes was 2,000 tons per hour. Iron ore was loaded at the rate of over 7,000 tons per hour, and discharged at the rate of over 3,000 tons per hour. Individual records were much better than these figures. These are real figures, but he ought to say these special boats had a very large number of hatches, and of course the machinery was in proportion to the number of hatches, so it was perhaps not quite fair to compare the American and Canadian practice with that of this country.

Sir John Aspinall said that their docks all over the country were by no means so well equipped as the docks of foreign countries. At one of their greatest ports from which Mr. Musker came, namely, at Liverpool, there were seven miles of docks on the Liverpool side of the river, and there was not one crane by which you could lift a ton of goods out of a ship and put it into a wagon, nor was there a crane by which one could take a ton of goods out of the wagon and put it into a ship. Mr. Musker's point was that the transit sheds or warehouses had been misplaced. Liverpool was a striking instance of that, as the transit sheds were placed within about 4 ft. of the water, and there was no room for a track to run between the ship and the warehouse. It was true that there were cranes on the warehouse roofs which discharged the ships very admirably into the warehouse. They put the cargo either on to the upper floor or on to the ground floor, but every ton of goods had to be handled twice. When one remembered that very often contracts were given based upon some slight difference of 2*d.* or 3*d.* a ton, was not it worth while trying in some way to get rid of these extra charges which would amount to a great deal more than 2*d.* or 3*d.* a ton? Then when one came to the interior of the transit sheds and the warehouses, one found they were woefully lacking in appliances for handling the stuff that had to be stored.

Mr. Musker was right when he spoke of the desirability of building high buildings with cranes running overhead, so that one could store material at a considerable height. When the cargo happened to be cotton, or wool, or merchandise in cases, there was no difficulty about storing to a great height, and if one had got rapid working electric cranes, rapid in lifting in cross traverse and in longitudinal traverse, one could do the work so quickly that it did not matter if, when one wanted a bottom bale, one had to shift the upper bales. When he was the General Manager of the Lancashire and Yorkshire Railway he felt that the old system of building warehouses, great solid warehouses with many floors, for the storage of cotton in Lancashire was a mistake, and they erected quite a number of open buildings with fast travelling cranes, and stored their cotton in them. All sorts of prophecies were made that such an arrangement would be a failure, but actually the result was that they got their work so rapidly done that many of the carting agencies preferred to come to their warehouses in order to get their bales quickly rather than to go to the others where they were dealt with in the old fashioned way. Going back for a moment to the question of loading and unloading of ordinary cargo from a ship, one had to recollect that so long as they had a Customs and Excise Authority, a vast quantity of material that came out of the ship must be put down on to the ground for examination.

On the other hand, with a rough cargo, much could be put straight into the vehicle that was going to take it away. When one came to put material on board a ship, certain classes could always go straight into the hold. Other classes had to depend upon

the stevedore's knowledge as to how they ought to be stowed, and therefore they had to wait their turn. Hence, one could not lay down as a rule that everything could be taken straight out of a ship with one handling, or put on board a ship with one handling; nevertheless, there was an enormous amount of stuff that could be so dealt with, and great improvements were possible. When one came to the question of dealing with coal which the Chairman had spoken of, really in this country they were doing it very badly, save at the north-east coast ports, where their coal was put on board ship by means of staithes, and they had not got to have lifting or dropping appliances. They used drop bottom wagons of considerable capacity, though of nothing like the capacity that the Chairman had indicated in his remarks. Leaving out the north-east coast ports, 77,000,000 tons of coal were shipped in 1913 at other British ports either for bunkering or for export. Practically the whole of this coal was tipped out of 10-ton wagons. These small wagons occupied a great deal of room, but it might not be possible within the limits of reasonable expenditure to go in for very much larger wagons, as many of their docks and their ports had such cramped spaces, and many of the collieries themselves were difficult to get at, yet it certainly was possible to double the capacity of those wagons. In that case the 77,000,000 tons that he had mentioned could be shipped with 55,000 fewer wagons, worth at present prices about 14,000,000*l.* or 15,000,000*l.*, which should be diverted to some other useful end. Many of the appliances used were made 40 years ago. Taking the whole coast of this country there were only 288 appliances which wanted altering; but until this was done 20-ton wagons could not be used.

Mr. Scrutton said they all felt that the old-fashioned methods of handling had broken down, not only for reasons connected with the war, but prior to that. The increasing length of ships, the increasing size of sheds and accommodation brought out two dominant factors, viz., that the hand truck was useless, and that the hydraulic crane was limited in value. The increasing length of the jib had caused a slowing down in output. His firm had tried to avoid the use of the hand truck in taking cargo direct from the ship's hatches to the shed centres by adopting belt conveyors, and they had thus doubled the output. As the men were nearly all paid on piecework, they doubled their wages, whilst the employers cleared themselves from the so-called standard wage, which was rather an artificial condition. Their second experiment was to make use of the cargo elevator from the ship's hold. He was hoping that the present Port Authority in London would look seriously into the question of the placing of elevators to assist the crane on such portions of the cargo as could be suitably dealt with in that way, such as what might be described as bag and parcel cargoes. They found, dealing with such articles in a constant stream, they maintained their output, because there was a weak spot in the discharge of cargo by derrick or crane, namely, that one was entirely at the mercy of the human element, whereas if one employed mechanical power the output was maintained during the day with great regularity. He would like to say one or two things about the coaling question in London, but the larger employment of oil fuel made shipowners reluctant to put down special plant for handling coal. In designing docks and berthing accommodation it was only cost of materials which appeared to be thought of primary importance. The question of handling expenses was ignored, but it was the keynote of the whole situation. What happened now was that a designer might reject a certain provision of berth, because it would possibly cost him 10,000*l.* or 20,000*l.* more than the original estimate of 100,000*l.*, but the saving on the berths wasted in wages 15,000*l.* a year.

Mr. Menteith said that in handling cargo it was one thing to handle it from the ship to the transit shed, but it was another thing after it had passed from the transit shed into the warehouse, in which the cargo took on an individuality. Each package or bale then became something on its own. It had to be so placed that it could be sampled or delivered to its particular number. That was one of the reasons why they were still maintaining low warehouses in London, but it should be observed that the London Building Act limited the cubic capacity. He thought, as Mr. Musker said, a great many improvements could be effected in some of the very old fashioned cranes which one saw—no doubt they were out of date—and also with regard to the trucks, but the class of cargo handled in London was of a retail character, and there was not the same need for big sheds as at Manchester.

Mr. Davis said that at Liverpool the methods of handling goods were of a most elementary kind; the waste of time and the consequent expense was little short of deplorable. He had had occasion to obtain from America a consignment of steel plates and angles in sections, amounting to about 200 or 300 tons. They were wanted urgently, and the work could not proceed until all the materials were at hand. These materials came over from America in a 15,000-ton steamer. In this 15,000 tons there were about 6,000 tons of steel. The people on the other side, probably for reasons of stability, did not load the steel all into one hold, but they loaded portions of it into many holds. In consequence of being loaded in that way the steel was hopelessly mixed up, and when finally sorted out, it was found that about 8 per cent. of the materials that were required had miscarried. All these materials unshipped had to leave Liverpool by rail. It seemed preposterous that they should have had all to be taken off the ship, wheeled in trucks over an ill-paved road into a shed and mixed up with other cargo which made it difficult to get at them as they were surrounded by bales and all sorts of other things. Then thay had to be trucked again on to some horse or motor wagon, which carried them from the quayside to the railway station, and another sorting went on there. Had there been an arrangement whereby the rails were brought on to the quay the materials as they came out of the ship could have been sorted and put on trucks, and all the other expense would have been saved. He had, in connection with one or two concerns in which he was interested, to deal during the war with very large quantities of materials in works of his own. At the outset, the handling of this material over a period of about ten months had cost such an excessive sum as 8*s.* per ton. He then put in some travelling cranes, and thus reduced the handling charge from 8*s.* 3*d.* to something like 1*s.* 1*d.* per ton, and the work was done in a tithe of the time.

Mr. Victor Prigg said that Liverpool was at least 25 years behind times in the matter of handling freights, the most up-to-date port being at Manchester, where he had seen some of the most modern up-to-date appliances. One particular type was what was known as the cotton safes, where the goods were picked up on a conveyor and one had a cross-traverse, so that a man could pick up a bale at any point and run it laterally along the frontage of the warehouse, and then could carry it right in at right-angles into any of those safes, and deposit it there. For dealing with sack goods they had conveyors and stackers which were made in suitable lengths, and readily adaptable, to any part of a warehouse. Sack goods were thus transferred from the truck to any point by putting in what sections were required. The man in charge had to keep time as the sacks arrived, so there was not much opportunity for slacking. With regard to grain, on the dock-side there was a new granary which had been opened since the outbreak of war. The grain was handled automatically from the ship's hold from which it was sucked up, and then carried along by belting to the silos, and from the silos weighed out automatically into the sacks. As far as he knew, the most up-to-date appliances for the general handling of goods were at Manchester. Plymouth, from whence he came, was certainly out of date, though some 15 or 20 years ago he reported on a scheme for handling coal there, but the cost (40,000*l.*) was considered so excessive that the coal was still transported by men carrying it on their backs in sacks. He was rather surprised to hear that in London they simply dealt with 45 tons of coal per hour. They had one coal depot at Plymouth where the discharge of cargo was done by grab and by a traversing electrical crane conveyed right into reinforced silos, where it was taken off as required to the weighing machine.

Mr. Monkhouse said that one speaker had stated that the London County Council regulations provided that a shed could not be built of more than 250,000 or 300,000 cub. ft. capacity. He did not know what width would be needed for a warehouse, but assuming that 60 ft. wide would suffice, then with a height of 34 ft. to the eaves they could get a shed 116 ft. long. This difficulty as to cubic capacity was, however, quite easy to get over. All one had to do was put in some sort of partitions, but those partitions did not need to be fixed partitions at all. They could be movable, and one could have very large doors or sliding partitions, and he had come to the conclusion that that regulation did not, and would not, interfere to any great extent with the work in a large building. He had had himself to design an engineering factory which had considerably more cubic capacity than the London County Council would permit in one piece. They got over the difficulty by arranging for movable partitions. He was with Mr. Musker and the other speakers on the necessity for having improved appliances for handling cargo, both on ships and ashore, but anyone who had travelled much at sea knew that all cargoes were not bulk cargoes; and not all cargo could be handled by elevators or suction plants, or similar apparatus. There was what one speaker referred to as the parcel trade, in which very small parcels had to be dealt with one by one. It was the handling of those parcels and articles which really presented the greatest difficulty, and in which there was the greatest waste of time. Their chairman had spoken of very large ships, and the handling of large quantities of cargoes like coal and iron in a very short time in America. It was quite true they did all those things in America. If we were rebuilding our docks and wharves to-day, he supposed we would put up cranes and apparatus and berths in which these very large quantities of material could be handled. We had started, as everybody else had started, in a small way, and there were not many people who had the courage to scrap apparatus before its cost had been written off the books. There ought to be more co-operation between shipbuilders and dockowners, or designers of docks in the matter of lifting appliances. The lifting appliances on the ships which did the cargo trade were very poor, and the hatches were often far too small. In any move that was made towards improving these mechanical appliances for handling cargoes, he thought the shipbuilder, or shipowner, should be called into counsel so that he might improve his part of the business as well as the dock designer.

The Chairman thought this note had brought forth an excellent discussion. He would like to make one or two references to what had been said with regard to the action of the unions in relation to their men. He felt quite confident that the unions would arrange proper terms provided the machinery for loading and unloading was improved commensurate with other improvements. They were doing that in connection with the other great engineering industries, and he saw no reason why they could not do it also in that particular department of engineering. He was sure none of them wanted to make the position of the men worse than it was. On the contrary, they all wanted to make it better. He felt that by increasing the facilities for loading and unloading they would reduce their costs; they would do their work more efficiently and in quicker time, which would bring more trade to this country, and would employ more men, and would give them better wages. He thought that was quite a fair and proper way of looking at it. With regard to the last speaker's remarks about America, the few words he had said at the commencement applied equally to Canada, which was part of the Empire. The facilities for loading and unloading in the Canadian ports were quite as up-to-date, if not more so, as any in the United States. He would make that as a special point because it was done by their own countrymen in the Empire. The remark that was made that the port of Manchester was the most up-to-date port was very creditable to the port of Manchester, but he did

not quite know what to say concerning the other remark about Liverpool being 25 years behind. The majority of the speakers had left on him the impression that their loading and unloading facilities were hopelessly inefficient, and involved undue costs and terrible delay to the shipper. He felt that the various municipalities and important shippers in this country should see that these facilities were increased and improved, and that the engineer was used to the fullest possible extent to increase that efficiency, and so bring more trade and commerce and employment to the people of this country.

Mr. Musker felt that the speakers had been so much in agreement with what he had put down in his note that he had nothing to reply to. They had all agreed that everything was deplorably out-of-date.

SECTION IV.—MINING AND METALLURGICAL PROCESSES.

DAMAGE TO TYRES AND RAILS BY BRAKES OR SLIPPING WHEELS.

On the members of this section reassembling on Thursday, June 30, Sir Robert Hadfield occupying the chair, the first paper taken was the one having the above title by Mr. C. P. Sandberg. We reproduce this on page 82.

Mr. S. L. Murgatroyd said the paper added another feature to those the permanent-way engineer already had to take into consideration when examining his line and determining whether the time had arrived for a length of rail to be relaid or not. It was necessary that the greatest care be taken in examining the rails at bridges, stations, junctions and other places where the application of the brake on the trains was habitually made; particularly those places where an engine or a train was likely to be stopped. In such places when re-starting the driving wheels frequently slipped, and it was there that the greatest danger arose because heat was generated at that point, and it was local. When the train was moving and the brake was suddenly applied, and the train slid over the rails, the heat was not concentrated on one point to the same degree. Generally, on examining the fractured rails, he had formed the opinion that fracture was due to segregation in the steel, or to a flaw induced by excessive wear. This was often termed "hammer hardening." It was, however, clear from the author's experience that quite sound steel might develop small cracks by reason of the heat generated locally between the slipping wheel and the rail, and these cracks, aided by the bending action of the rail which was supported at intervals on sleepers, developed until eventually fractures took place. It was to be noted that in tramway rails, which were continuously supported, the same effect took place, but there no bending action occurred as in the railway rail. The cracks therefore did not develop but were eventually worn off. Recently on his company's system a rail had broken in five places. The original weight of this was 95 lbs., and it had been reduced by wear to 84 lbs. a yard. That would mean that three-eighths of the top flange of the rail had been worn off. Under normal circumstances a reduced weight such as that would be considered as having still left an ample margin of safety. Not being satisfied that the breakage was the result of what he had always previously considered the "hammer hardening," the rail had been submitted to Messrs. Sandberg for further investigation, and on their examination it had been found that the metal of the surface had been heated by frequent slipping of the driving wheels, because this was a point where frequently trains were pulled up on a sharp curve, and where there was a gradient and a junction. The wheels constantly slipped and caused spots where the temperature in the steel was raised beyond the critical point, and quenched by conduction of the bulk of the rail. A film of martensitic steel on the top showed under the microscope a number of very fine cracks, the rail in all other respects being absolutely sound and good. The question of how the difficulty was to be met was one of which various opinions would be expressed, but it seemed to him that the rails subject to the wheel-slipping action should be renewed before they became reduced in weight to a point normally considered unsafe, or the unsupported length of the rail should be reduced by the use of additional sleepers. Further, a tougher rail might be used such as was produced by the addition of silicon, or by using the Sandberg sorbitic process, or even a rolled manganese steel rail. That the toughness of ordinary steel rails decreased with age was clearly shown in what was known as the St. Neot's rail. In their report, Messrs. Kirkaldy, who had examined this rail, reported that its toughness had practically disappeared.

Mr. W. H. Shortt said that as far as experience on the South Western Railway was concerned, he did not think he could trace a single fracture in the running during the past seven years, on lines of the class quoted by Mr. Sandberg. The only fractures of that kind they had had, had been in the sidings, where the rails were of unknown age, and it was not very helpful or hopeful to make any investigations of them. However, as the result of Mr. Sandberg's experience, they were certainly going to examine very carefully the surface of all rails that showed any signs of having fractures clean through. In this country the number of fractures was really very small. His company had 1,800 single line miles of running line, and the number of fractures that they anticipated to occur in the year was somewhere about 20. As regards slipping, he thought his company were very fortunate, because with their electric stock the power was delivered through the bogies. The load on the wheels was about 10 tons. This was not a very severe load and, as far as starting was concerned, he had not yet seen an electric coach slipping when it was started. They might slip when they pulled up at times, but he had not seen that either. His company had only been troubled with severe side wear on curves, and there was no sign of snow burns or wheel burns. The only type of fracture they had been troubled with was the fracture that occurred between wing rails and point rails. In these cases, the fractures all started from the holes which were drilled in the rails to take the horizontal bolts which tied the wing rails to the point rails. In that instance they had experienced cases of cracks starting from a hole at an angle of 45 deg. and coming out eventually at the top of the rail. This was attributed largely to the fact that the holes were placed one on each side of the chair which supported the weight, and consequently at positions of maximum shear. Those holes were now being shifted to positions of minimum shear in order to obviate the occurrence of similar fractures.

Mr. C. J. Spencer said the paper was of very great interest to tramway men, whose problem was that of cost. On the London tramways they had to spend large sums of money every year in renewing rails at brake stops. An ordinary tramway rail of about 108 lbs. per yard was completely worn away in about three years at a busy stopping place. That wear was occasioned by the constant use of the magnetic brake. In order to get the best magnetic effect it was necessary to use a certain sort of rolled steel for the wearing surfaces, and that seemed to have this extraordinary effect of wearing the surface of the rails. During recent years, Mr. Sandberg had invented a system of rail hardening, and it seemed that now was an opportunity to moderate the cost of the renewal of these rails. But unfortunately it had been discovered that in consequence of the heating of the rail surface during braking, the benefits of that invention were not very high, and whilst it was to be regretted that Mr. Sandberg was not able to give more comfort than to point out where the trouble lay, yet we were some distance along the road when we knew the cause of our trouble. The expenditure in rails and shoes was a very serious matter, and if by further experiment some way could be found of getting rid of the extraordinary wear, the tramway industry would be exceedingly glad. He (the speaker) was sure the railways were grateful for the result of Mr. Sandberg's investigation. The expenditure on wheel tyres on an ordinary tramway was also very great. The wheel expense of an ordinary tramway system was a great deal higher than that of a railway. Tramways were operated under very much worse conditions, and tramway engineers had for years been asking for tyres of a very high tensile strength. If what Mr. Sandberg said was correct, it did not appear that there would be any benefit at all in buying tyres of high tensile strength, for the destructive effort on the surface of the tyre from the brake-block was apparently the same whether the tyre was of low or high tensile quality. As a matter of fact, high tensile steel gave very much better wearing results than the old soft steel. This had been always considered, probably wrongly, to be due to just ordinary wear; but if it was due to this involuntary heat treatment consequent on the crumbling away of the surface, it would seem that we ought to get the same sort of evil results with the hard tyre as with the soft tyre. But this did not quite square with experience, and perhaps Mr. Sandberg would deal with the point in his reply.

Dr. Rosenhain said it was not a new discovery that steel could become martensitic by the effect of friction and the consequent evolution of heat, and rails and tyres were not the only things that suffered in this way from surface heat. There were one or two consequences which the closer consideration of the matter involved that were, perhaps, worth mentioning. First of all was the inspection of rails with a view to detection of cracks of this kind. In America a practice had been developed of testing the magnetic permeability of the rail. In places where this kind of action was to be feared a careful inspection of the rails should be undertaken. This question of the magnetic inspection of the rails would be of considerable interest; one could not tell when looking at the surface whether the crack was a surface crack or had gone in. But a magnetic test would discriminate, and would warn the inspecting engineer of such deep fissures. The next thing was that the martensite was formed when steel was heated above the critical range and cooled very rapidly. But the cracking of the martensite, and the amount of difference between it and the normal structure of the steel was very much greater in high-carbon steels than in low, and he would not be surprised to find that the increasing tendency to the use of higher carbon in rails and everything else had to some extent intensified this particular evil. It did not run concurrently with the number of fractures of rails, or the life of tyres, because apparently this was not by any means the only factor. High tensile tyres gave longer wear than the others, but, as far as this point was concerned, one would expect them to be worse. Therefore, there must be other factors as well. The trouble in this case was due to the generation of an excessive amount of heat, and the production, as the result of that heat, of a temperature exceeding the critical range of the steel locally and generally.

There were two ways of lessening that: one was to reduce the amount of energy caused by friction, and another to get rid of the heat by conduction. Taking the second point first, it was found in a totally different field of engineering—that of internal combustion engines—that heat could be got rid of by the use of metals of high thermal conductivity. Aluminium and its alloys were used for that purpose and, he thought, might be used for brake blocks. The use of such a metal, which had, approximately, four or five times the thermal conductivity of iron or steel, and had also a very much higher specific heat, would very much lower the maximum temperature obtained on the friction surface; and if on trial other difficulties did not appear too serious, it might act as an appreciable remedy. The strength and durability of the material were ample for the purpose. It would be a comparatively cheap material. It could be used in the form of cast blocks, these being fairly large. The second point was more difficult. It was not so easily tried, and there were many more considerations to be borne in mind. It was that the amount of energy which had to be dissipated depended on the kinetic energy of the moving vehicles, and consequently, assuming speeds to be constant, on their mass or weight. Railway and to some extent tramway engineers, had not troubled very much about keeping their vehicles light. The tendency had been towards constantly increasing weight. Of course, there were considerations in

which weight was good and necessary, but, on the other hand, it had not been realised—particularly in electric trains where frequent stoppings had to be done—what a large proportion of the power consumed went to wearing away tyres and rails in starting and stopping. Without considerably increasing the cost of vehicles, or diminishing their strength, this weight could be reduced. There were various ways of doing that, and one would be the adoption of lighter scantlings, made of steels of very much higher strength such as were now available. That was one possibility, another was the use of aluminium alloys for the construction of under-carriages and other parts. These materials were now available in the wrought form, of ample strength, durability and permanence. They were expensive, but there was no doubt that a very considerable saving of weight in tramway vehicles and in the driving units of railway vehicles could be effected by their use. In many cases a half or two-thirds of the weight could be saved. All these things told in wearing out the rails.

Reference had been made to the failure of the St. Neots rail, and a statement made that the conclusion might be drawn that the toughness of rails decreased with age. He did not think the statement justified, and he challenged it. It might be in certain cases, where the rail was undergoing severe treatment, that deterioration made itself felt in that way; but that was exceptional; and the mere fact that a rail in the track was being bent backwards and forwards and hammered on the surface, could produce no deterioration unless the stresses exceeded the elastic limits locally and led ultimately to fatigue fracture. He had tested rails which were in some cases 60 years old, and there was no evidence of deterioration except on the surface, where the steel had been hammer-hardened by the blows of the wheel. But that did not penetrate to any depth below, and it was altogether exceptional to find any indication of change of properties. The old idea that metals suffered damage as the result of vibration had been thoroughly disproved by modern investigations. There were special cases where rails had deteriorated, but that was not the general rule.

Dr. Hatfield said the St. Neots rail had these minute transverse cracks. That had been determined by Dr. Stead at the time. But one must look upon the formation of this martensite layer—of very small thickness indeed—as an inherent property of both rails and tyres, and it would be rather a pity if that fact were in any sense, as suggested by Dr. Rosenhain, to lead them to lose their interest in the use of higher tensile tyres and rails. If they wanted to decrease their wear in tyres and rails they must increase the hardness. They were doing that cautiously; for instance, for the last few years they had steadily increased the hardness of their tyres. They had progressed with experience and were now at 60 to 65 tons per sq. in. in their tyres with perfect safety. One reason why, at any rate in the rail, they might look with not so much misgiving on the feature of the skin hardening, was that in the rail these cracks were on the abrasion surface. Therefore they tended to close up rather than to open out under actual service conditions. He would like to confirm Dr. Rosenhain's view that rails and steel generally did not lose toughness with age. He thought that had been established very clearly and firmly as the result of a vast number of investigations.

Mr. C. P. Sandberg said he was delighted to find the general interest that had been taken in his firm's investigations into this matter, and he thought they were especially fortunate in having several of the leading railway engineers of the country coming to the metallurgical section when they probably had more interesting papers in their own section. After all it was engineers who were directly affected by the types of defects he had pointed out. Mr. Murgatroyd had recognised the desirability of renewing wheel burnt rails and that was all that was necessary as a start. If a railway engineer carried out a systematic investigation or inspection of his track where this type of defect was likely to occur, he had done something to safeguard the travelling public, and as the defects were easily discernable, most railway engineers would, at a very small cost, examine the places where these defects were likely to occur. The actual cost of taking those rails out and putting new manganese steel ones in was a very small matter. The total mileage where this sort of defect was at all likely to occur was not a very large one. In regard to the St. Neots rail, it was quite correct that the micro-cracks occurred right through the rail. As to the safety of home railways, this was a thing that he hoped we should be able to be proud of for years to come—in spite of increased loads, greater traction and generally greater strain. We were fortunate in that the foresight of our older engineers had insisted on an excess of safety of the permanent way. In America they counted the number of derailments, but not the number of fractures; while in our Board of Trade reports we enumerated every fracture. He took issue with the Board of Trade on this matter; he thought that for purposes of international comparison the Board of Trade should enumerate these fractures as failures of material but not as accidents unless the particular fracture definitely caused the derailment.

Mr. Spencer had placed him in a very difficult position. He (Mr. Sandberg) had brought forward matters which he thought would be of professional value, but Mr. Spencer had brought forward their name in connection with their own inventions, where he (Mr. Sandberg) had wished to avoid self-advertisement of any kind. He would ask Mr. Spencer to admit, as he was sure he would, that the mileage of tramway track in the country where that very serious reduction in the life of rails at stopping places was caused by the action of the magnetic brake was probably not 5 per cent. of the mileage of the country—that was to say where the magnetic brake was used as a service brake. Unfortunately Mr. Spencer had got part of that 5 per cent. Dr. Rosenhain had put forward the very valuable suggestion of using brake blocks of aluminium, or of an aluminium alloy. Mr. Spencer had only told part of the story; wherever the sorbitic hardening process had been applied, not only was corrugation arrested but the resistance of the rail was increased by two-and-a-half times. These were the average figures of 120 miles of tramway track now treated by this process. Mr. Spencer had asked about the wear of hard tyres. It was quite true you might assume that if this defect occurred both on the rail and the tyre, the harder tyre would not wear any better; but Dr. Rosenhain had practically answered the point. Mr. Spencer would get out of his trouble if the brake was applied very gently and very gradually. Dr. Rosenhain's suggestion of a test which would really definitely say whether you had got a micro-crack, or a crack of possibly an inch depth, was a very valuable one; if it could be applied in a cheap and practical way, he was sure that railways would be very much interested to hear more about it.

The Chairman thought the trouble in America largely arose from the fact that they used unsound steel. They turned out such a large quantity in such a short time that they had not the proper opportunity of getting a sound product. The defects often form internal flaws in the steel; if you made your steel sound in the first place many flaws would be avoided. About five years ago the Pennsylvania Railroad had allowed him to send out about 100 tons of ingots made of sound steel, and he was not aware that there had been a single failure in the rails made from that 100 tons. In America they had much heavier engines than we had, because they had longer trains, so the rails were more severely tested. Mr. Sandberg had referred to manganese steel rails, but engineers could not be expected to pay the higher price unless they were first convinced they were getting value for their money.

Mr. Spencer asked to make a personal explanation. He was exceedingly sorry that his good friend Mr. Sandberg thought he had in any way made an attack on his system. He agreed with and confirmed all that Mr. Sandberg had said in reply.

The Elastic Limit.

The second paper was the one having the above title, by Professor W. E. Dalby. We reproduce it on page 81.

Professor Coker, who opened the discussion, said all recognised the great beauty of the experiments which Professor Dalby had made on the stress-strain curve in materials. He thought the great point was that Professor Dalby had first of all devised a machine in which the human element was practically eliminated. With an autographic machine one had the advantage of being able either to take the test in a second or two seconds or to prolong the test for a considerable period. He (the speaker) agreed about the detrimental action of gauge points, and had shown how very injurious it was to have points and extensometer markings on a test piece, especially when very short. At Professor Dalby's suggestion he had made rather an extensive investigation of the stress distribution round the collars which Professor Dalby used in his test pieces. There was of course somewhat of an alteration which was close up to the collars, but it probably did not appreciably affect the results of the test. In fact he (Professor Coker) thought that Professor Dalby had approached as nearly as possible the ideal of getting his tests from the straight bar. He had been rather curious to know whether Professor Dalby would give a new definition of the elastic limit. They all knew how very difficult it was to find where that limit occurred, because, if it was the limit of proportionality, usually the load extension curve went off very gradually even with the autographic record. He would like to ask Professor Dalby whether a closer limit might not be got with his machine. If Professor Dalby took a second test bar and made experiments with loop diagrams repeated at reasonable time intervals up and down just about where the elastic limit was believed to be, then the test would be whether you got a loop with an area, or not. It appeared to him (the speaker) that one would be able to define the elastic limit much more closely in that way possibly than by the records of a single diagram taken to fracture; because if within the elastic limit of the material one would get a loop, an area, and if not then one ought to get a series of straight lines on the diagram.

Dr. Rosenhain said the question of the elastic limit was one that was coming increasingly into the field of practical engineering, and accordingly one must welcome Professor Dalby's present offer to bring about a better understanding of the meaning of the term, because so many people in practice used as if they were synonymous the terms "yield point" and "elastic limit." This was a very great mistake. The author's curves showed that the distances between the elastic limit, the limit of proportionality and the yield point varied very widely. In his own (the speaker's) experience, one of the characteristic features of steel in an unsatisfactory condition of structure was that it showed a very great distance between the limit of proportionality and the yield point. On restoring that steel by suitable heat treatment one brought the two points closer together. It was misleading to judge of the quality of steel by its yield point. This was being done all over the country, and it was time engineers began to realise that the phrase had very little meaning. The yield point did not matter for anything that he was aware of in structures or machines. He thought there should be two terms in use, "limit of proportionality" and "limit of restitution." Both terms depended on the question of how accurately one measured the changes of dimensions. The question of loops was one of interest and very great importance, but he was afraid Professor Coker's suggestion would not work. The elastic limit could not be found in the way proposed. There was a certain thermal effect due to elastic stretching, in some cases a rise of temperature, in some a slight fall. If one allowed time for that to be lost, energy had been lost; and when the load was taken off one was bound to get a loop. The mere existence of a minute loop would not necessarily prove the departure from elastic properties. He had been very much interested to see the large difference of areas of loops in different metals. He had done some experimental work himself in which the amount of heat generated in the slow stretching of a piece of metal had been measured and compared with the mechanical work done. The heat generated was always less than the mechanical work done

because internal changes were brought about in the metal and these absorbed energy. The ratio of heat found as sensible heat to work done by the testing machine varied very widely in different metals, apparently much in the same way as the areas of the loops that Professor Dalby had shown. In iron particularly the amount of heat generated was very nearly the whole of the work done; consequently one would expect very little internal work to be done by a small amount of stretching, and therefore one would get only a small loop. In copper the loop would be large, and in aluminium much larger still. That was a question relating intimately to the latent heat of fusion and the melting-point of the metal. Metals of low melting-point had large loops and those of high melting-point had small ones. Broadly speaking, the loops showed the kind of action that went on in the metal when it was stretched beyond the elastic range.

Dr. Hatfield said whilst there was some difficulty in arriving at an agreement in words as to what engineers meant by "elastic range," they always understood what they meant when they used the term. They meant that range during which the steel responded as a truly elastic body. Bearing on that, the loops of Professor Dalby were of very great interest, and he would like to ask whether Professor Dalby had a series of loops done on the same material at varying ranges of stress. The loops shown were apparently loops obtained by exceeding the limits of proportionality. It would be of interest to see a series of loops of gradually descending and ascending elasticity; if that could be done on several materials, the information derived would be of very great importance. Presumably those loops below the elastic range would cease to exist as loops and we should simply have the lines. If we could ultimately by means of Professor Dalby's method decide what the elastic range of material was, this would be of great service for purposes of design. At the present time to obtain the true elastic limit of material one must have recourse to fatigue tests, and these took a long time. It would be interesting to see if the work of the National Physical Laboratory could be correlated with experiments and evidence obtained by Professor Dalby's method.

Colonel Carnegie asked as to the expense incurred in the manufacture of the collared test pieces called for, and as to the application of the instruments suggested in actual measuring tests. How far would the results obtained justify the expenditure. He considered from the point of view of experimental evidence, and for tests to ascertain the various qualities of steel, there was no doubt whatever that the machine suggested would be advisable.

After another speaker had referred to tests carried out with pendulum springs Professor Dalby, in replying, said he had loaded and unloaded by gradual steps up and through the limit of proportionality, and right over the yield point, and had found—taking a piece of ordinary steel—that one had a straight line without any observable area until one passed the limit of proportionality. Between O and the limit of proportionality engineers were really dealing with the average behaviour of a number of crystals embedded in the structure, and they knew—provided they did not exceed this limit of proportionality in their structures—these stood indefinitely. Those are the facts which justified their reliance in putting materials in and relying on the limit of proportionality as the point beyond which they must not go. He thought a good many papers read before the Royal Society showed the small loop; in all kinds of materials when one departed from zero some hysterisis, or departure from a straight line was, he thought, quite well recognised. There was no real law about it. It was found by experience that materials obey Hooke's law and he had been trying to find metals which did not. Dr. Rosenhain's remarks made one feel what an enormous field remained to be investigated. As many workers as possible were wanted in this, and fortunately Dr. Rosenhain and he had been able to work together a good deal at the National Physical Laboratory and to exchange results. He quite agreed with much that Dr. Rosenhain had suggested about the limit of proportionality and the limit of restitution. These were two terms which in some way ought to be considered, and if possible brought into practical use. The "limit of elasticity" was so vague a term, and was used in so many senses, that it was best not to use it at all. Of course the thermo-dynamic equation for tests was well-known. If a more accurate instrument was used, he thought the effect of the time load would be observable, but he did not think it could be observed with this instrument. Dr. Hatfield had asked whether he had used loads at varying speeds. [Dr. Hatfield: Varying loads at different speeds.] Professor Dalby replied that he had done this. He had had such a lot of plates that he had had to make a small selection for the lecture but he could show Dr. Hatfield some of the others. A very wide range of experiment could be observed in the thousand plates that had been taken by the instrument. The great point was to correlate the work. He would like to see a series of experiments on standard steels, all working with various tests so that we could correlate and find out how one property depended on another. At the present time there was a committee investigating the "hardness" of steel—a term which nobody could define. If that matter could be brought into consideration, and experiments correlated with other experiments, he thought the difficulty of defining hardness would be found to be merely a difficulty of words.

The Effects of Scratches in Materials.

The third paper was the one having the above title, by Professor E. G. Coker. We reproduce it on page 81. It was illustrated by lantern slides.

Professor Dalby said that he would like to limit his remarks to three points. The first was the extraordinary influence of the state of the surface upon the strength of the piece of material. The second point was that in dealing with materials, the polishing of a surface he thought it was generally agreed produced a film of amorphous material over the crystal structure beneath. The effect of scratching might be that you penetrated below this polished surface into the structure, and in that way got the surface stresses transferred to a point within, which started the particular distribution they had seen. His third point was that they would all agree that Professor Coker had devised a beautiful method for investigating this question, and that they would all like to record their admiration of it.

[We intend to conclude our report of the meetings of this Section and of others in our next issue.]

(To be continued.)

EXHIBITION OF BOILER-HOUSE APPARATUS.

The action of the Institution of Mechanical Engineers in arranging an exhibition of boiler-house apparatus in conjunction with their summer meeting is to be commended, and a very interesting collection of exhibits was to be seen at the Institution Building from Thursday to Saturday last. We do not know that the exhibition had an official title, but the name we have given it above sufficiently covers the greater part of the material shown. The main object of the display was to give makers an opportunity of showing, and members an opportunity of seeing, various appliances bearing on the main subject of discussion at the meeting, that was on the "Means of Improving the Thermal Efficiency of Heat Power Plants." The arranging of a specialised exhibition of this kind on a semi-private scale gave engineers an opportunity of seeing and talking over the appliances shown in an atmosphere and in a way not generally available at the larger type of public engineering exhibitions.

Owing to the very great pressure on our space consequent on the concurrent meetings of the Institutions of Civil and of Mechanical Engineers, it is not possible for us to deal as fully with this exhibition as we might have done under somewhat different circumstances. We will endeavour, however, to give a short review covering the majority of the important exhibits. Our task is rendered somewhat easier by the fact that the show contained much material which has already been described and illustrated in our columns. This was, of course, only to be expected as the exhibition concerned current material and was in no way confined to novelties. The field covered by boiler-house apparatus is one in which much activity is apparent at the present time and precisely for that reason it is possible for us to give many back references to recent issues of ENGINEERING in which material shown at Storey's Gate will be found described.

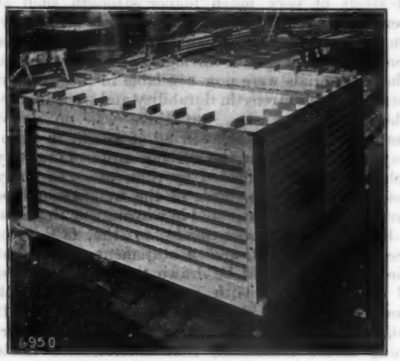


FIG. 1. THERMIX AIR HEATER.

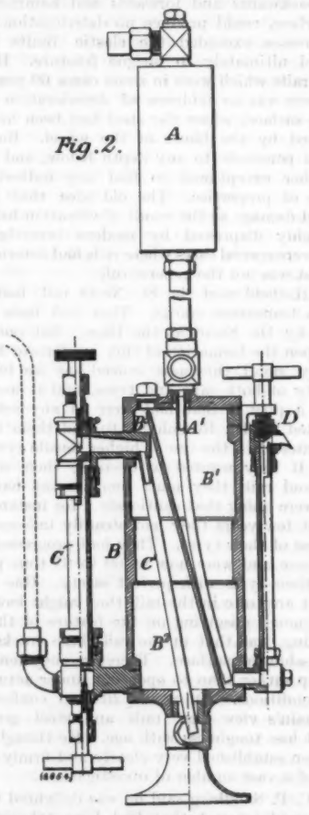


FIG. 2.—SIGHT-FEED LUBRICATOR FOR AQUADAG.

The general impression left by the exhibition is that very great attention is being devoted to the design of apparatus for the purpose of measuring some of what one may perhaps call the accessory quantities in power plants. This is all to the good, but it is well to remember that the main materials consumed by a steam boiler are coal and water, and the first measurements an engineer in charge should make concern the quantities of these materials used. There are unfortunately very many boiler plants in operation in this country in which the only measurements of these quantities which are available are those furnished by the quarterly or monthly

PERMEAMETER FOR AIRSHIP FABRIC.

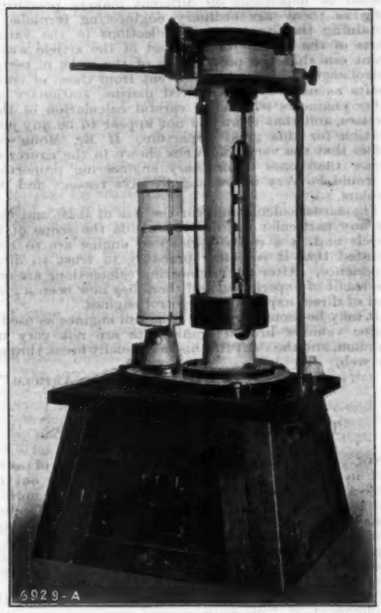
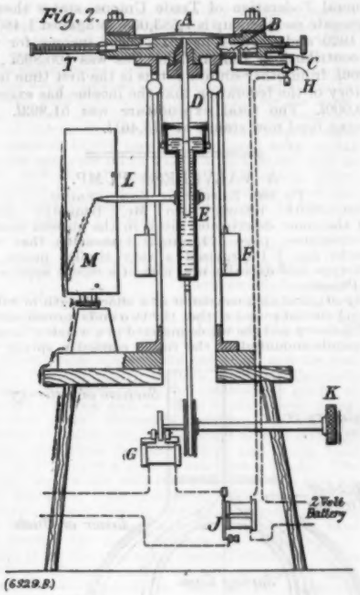


FIG. 1.



bills, and no arrangements are made for distributing the charge among the units of the plant and the various shifts. In this connection it is interesting to remember that in the United States during the war, when there was something approaching a coal shortage, priority in fuel supplies was given to firms having arrangements for the proper measurement of coal and water used.

We do not suggest, of course, that no apparatus for these measurements was to be seen at the exhibition. We merely suggest that appliances for the collection of secondary data were more in evidence. Coal measurement was covered by the display of Messrs. The Lea Recorder Company, Limited, of Manchester, who showed their coal meter. This appliance was described by us in our issue of December 6, 1918. Water measurements were covered by the exhibits of Messrs. George Kent, Limited, of Luton, Messrs. Alexander Wright and Co., Limited, of Westminster Palace Gardens, Westminster, and Messrs. Glenfield and Kennedy, Limited, of Kilmarnock. The appliances of these various firms are well known, but we may perhaps refer to the ingenious "Yorke" weir meter shown by Messrs. Wright. In this the integrating mechanism is greatly simplified by the form of the notch, which is such that the head over the weir is always in exact proportion to the quantity delivered. A description of the meter was given in our issue of October 31, 1913. In connection with this question of the measurement of coal and water we may refer to the allied matter of the measurement of steam. This was represented at the exhibition by Messrs. George Kent's steam meter, which we dealt with very fully on October 10, 1919. Messrs. The British Thomson-Houston Company, Limited, of Rugby, also showed their well-known steam meter.

Apparatus concerning feed water in one way or another was shown by United Water Softeners, Limited, of Kingsway, London, Messrs. John Thompson Water Tube Boilers, Limited, of Wolverhampton, and Messrs. Scholey and Co., Limited, of 56, Victoria-street, S.W. 1. The first two of these firms showed models, or drawings, of water-softening appliances, Messrs. John Thompson having a fine model of the "Kennicott" water softener which was described and illustrated in our issue of February 7, 1913. The plant manufactured by United Water Softeners, Limited, we have dealt with many times. Messrs. Scholey showed the Cope's feed-water regulator, which we dealt with on October 10, 1919. An appliance having reference to feed-water matters was the Chadburn-Empson salt detector which was shown by Captain A. W. Empson. It is manufactured by Messrs. Chadburn's (Ship) Telegraph Company, Limited, of Bootle, and was described by us in our issue of August 6 last year. An appliance for indicating the density of water in a boiler was shown by Mr. S. Utting, of 82, Victoria-street, S.W. 1. This was the "Kek" densimeter and consisted of a combination of two water gauges. One was an ordinary gauge and the other was fitted with a small condenser at the top and connected to the lowest point of the boiler by an internal pipe. As this pipe was filled with a column of distilled water the water in the second glass normally stood at a different level from the first. This difference in level was a measure of the density of the water in the boiler.

Mr. Utting also showed a model of the "Thermix" air heater. This is an appliance which is fixed in the boiler flue and heats the air which is used for combustion in the furnace. The appliance may be used in place of, or in conjunction with, an economiser heating the feed water. The principle of the air heater was mentioned in the discussion on waste heat utilisation which we shall report in our next issue. The appliance has been utilised to a very large extent on the Continent, and at the new Gennevilliers station in Paris six heaters of a total heating surface of 87,000 sq. ft. are being installed. An example of the heater is illustrated in Fig. 1, on page 56. The construction is simple and ingenious. It consists of a series of plates built up with distance pieces to form a nest of flat chambers. These alternately carry flue gas and the air being heated, and, as will be clear, a very large heating surface is obtained. The flue gases pass straight through, but division pieces are inserted in the air chambers forming bridges round which the air has to pass, the inlet and outlet connections being arranged side by side. In order to form a stiff construction each chamber opening has a wire helix clamped between the plates. This arrangement can be seen in the figure. The helices do not act in any way as springs, but form a simple and easily-constructed method by which the plates are supported across the openings, while at the same time little obstruction is caused to the flow through them.

Among other boiler details which were exhibited we may mention the furnace shown by the Turbine (Patent) Furnace Company, Limited, of 5, Budge-row, E.C. 4, which was described by us in our issue of November 12 last, and the "Hotchkiss" circulator shown by Messrs. Arthur Ross, Hotchkiss and Co., Limited, of 1, Glengall-road, Old Kent-road, S.E. 15, and described by us on October 25, 1912. Superheater fittings were shown by Messrs. H. and F. Danks (Netherton), Limited, of Dudley, who showed the "Grantham" superheater, the Great Central Railway of Gorton, Manchester, and Messrs. T. Sugden, Limited, of 180, Fleet-street, E.C. We dealt with two forms of Messrs. Sugden's superheater in our issues of January 14 last and August 10, 1917. Another railway exhibit was a fine valve gear model shown by the Great Northern Railway, Doncaster.

Among miscellaneous apparatus which was on show and which has already been described by us we may mention the de Laval oil separator shown by Captain Empson, of 39, Victoria-street, S.W. 1, and described by us in our issue of August 22, 1919; the "Usco" boiler draught indicator, shown by the Underfeed Stoker Company, Limited, of Coventry House, South-place, E.C. 2, and dealt with by us on October 24, 1919; the distance-reading thermometer of Messrs. Negretti and Zambra, of 38, Holborn Viaduct, E.C. 1, and illustrated by us on December 3 last; and the pyrometers of the Foster Instrument Company, of Letchworth, with which we dealt on October 25, 1912, and on March 18 of this year, the latter notice referring to the firm's "Resilia" mounting for pyrometer voltmeters. There were many other exhibits of interest and importance, including a new form of CO_2 indicator and recorder shown by the Cambridge and Paul Instrument Company, Limited, of 45, Grosvenor-place, S.W. 1, but considerations of space prevent us dealing with them.

The only other exhibit to which we can refer at the moment was a novel sight-feed lubricator for Aquadag, which was exhibited by Messrs. Dewrance and Co., of 165, Great Dover-street, S.E. 1. This lubricator, which is known as Johnston's patent, is illustrated in Fig. 2, on the opposite page. It has been specially designed for feeding Acheson Aquadag, and has been used particularly in connection with cylinder lubrication. The principle on which the appliance works is that of keeping a buffer of paraffin between the Aquadag and a head of condensed water. The lubricator is fitted with a condenser A at the top and when it starts working chamber B^1 is full of paraffin and chamber B^2 full of Aquadag. As the condensed water comes down the pipe A^1 the paraffin in chamber B^1 is floated over the weir B^3 and lies on top of the Aquadag in chamber B^2. This forces the Aquadag forward up tube C^1 and through the nozzle, the drop falling downwards through the sight glass C on account of the Aquadag being heavier than the paraffin with which the tube is filled. The refilling of the lubricator is done through a filling cup and the levels of the water outlet D, the paraffin weir B^3, and the filling cup, are so arranged that the three liquids are in balance as soon as the lubricator is full, so that no more Aquadag will run into the filling cup.

PERMEAMETER FOR AIRSHIP FABRIC.

THE workshop instrument for determining the permeability of gas leak through airship fabric, which we illustrate in the photograph, Fig. 1, and the diagrams, Fig. 2, on this page, was one of the exhibits of the Air Ministry, shown by Major S. C. J. Stewart and Mr. E. A. Griffiths at the June Soirée of the Royal Society. The permeameter is originally of German design, having been manufactured in the Riedinger works, Augsburg, and on the occasion mentioned a photograph was also exhibited showing the instrument in the damaged condition in which it had been surrendered. The damage was repaired in the instrument workshop of the Air Ministry. As now illustrated the permeameter is in working order.

The sample of the fabric A under test is clamped over a shallow gas chamber, the bottom of which is on the one side formed by a diaphragm B. Hydrogen is admitted into this chamber through the valve C. The glass tube D, the exact bore for which must be known, extends downward from the gas chamber and enters the mercury cistern E, which is counterpoised by the weight F. When the cistern is released it moves upward. This motion is controlled by an electric brake G, which is itself governed by the gas pressure in the chamber. As the hydrogen leaks away through the fabric the pressure in the gas chamber decreases, and the diaphragm allows electric contact to be made at H.

The relay J in circuit with the small battery (2 volts) is then closed, and the mercury cistern, being released by the brake, will rise until the gas pressure in the chamber has been restored to its former value. The brake can be adjusted by means of the reset wheel K. This play of the relay will call forth a step-by-step motion of the cistern, and this motion is recorded by the style L on the chart of the clock-driven drum M. The abscissa of the chart is time, and the mean slope of the step-curve thus indicates the rate of leak in terms of the bore of the glass tube D. The temperature of the gas is measured by the thermometer T.

INDUSTRIAL NOTES.

The settlement in regard to the wages in the engineering trades, referred to on page 13 *ante*, is as follows:—

The employers are of opinion that owing to the present state of trade the following deductions in wages are essential: (1) 3*s.* per week on time rates and 7½ per cent. on piece-work prices; (2) 3*s.* per week on time rates and 7½ per cent. on piece-work prices (being the amounts awarded under Award No. 180 of March 10, 1920); (3) 12½ per cent. and 7½ per cent., being Ministry of Munitions bonuses. With regard to the third stage, the employers agree to meet the unions in conference in September, to discuss whether the state and prospects of trade, as at that date, have so altered as to warrant a modification in the amount and also to fix the period over which it should be spread.

The representatives of the unions are unable to accept the opinion of the employers, but they are prepared to recommend that the first two stages should be given effect to as follows: First stage, July 15, 1921; second stage, August 15, 1921, and that the third stage should be reviewed at the conference in September.

As will be seen, the trade unions agree to the wage reduction of 6*s.* per week for time workers and 15 per cent. for piece workers, but the additional cuts are to be held over for the September conference. The employers' representatives agreed to recommend to their local associations the acceptance of the memorandum.

As stated in our last issue, an agreement has been arrived at between the colliery owners and the miners, and the mines are gradually being worked again. The coal strike lasted 13 weeks, and the loss it has brought about, in miners' wages; iron, steel and other workers' wages; wages in other trades and State expenditure, is stated to reach a total of 257,000,000*l.* The districts ballot in regard to the agreement showed the following figures: For acceptance, 832,840; against, 105,820; a majority for the terms of 727,020.

Mr. C. C. Joys, New York district, sales manager, Steel and Tube Company of America, has returned from a sojourn of three months in England and the Continent. *The Iron Age*, New York, gives his impressions as follows: "To visit England during the last three months is seeing the Kingdom at a great disadvantage. Due to the coal strike, every basic industry is practically at a standstill. Eleven weeks of this calamity has brought about a depression from which it will take months to recover after production is again resumed, and aside from the blow to industry, will undoubtedly cause considerable suffering during the winter months. By subsidising the miners, as the Government has offered, it is difficult to believe this same method of a 'forced peace' will not spread to other classes of labour, the results of which may be very serious. In addition, 'the wage for the unemployed' cannot but lead to higher taxation. Germany is working night and day, and seems to be on the road to a great recovery in all lines of endeavour."

The National Federated Electrical Association, 11, Southampton-row, W.C. 1, has instructed its members to give their workmen notice of reduction in wages. The notice states that in accordance with the agreed recommendation of the National Conference of the National Federated Electrical Association and the Electrical Trades Union at York, April 20, 1921, a reduction of 10 per cent. in the rates of wages current in April, 1921, will be substituted for the present reduction of 5 per cent.; such variation to take effect as on the first pay day following July 9, 1921, for the period covered by that pay day.

This reduction will apply to all grades of the National Wages Agreement for the electrical contracting industry, to journeymen, mates, assistants and foremen, but in the case of foremen paid by the week under any existing arrangement which provides a minimum difference between the foremen's wage and operatives' wage, such difference is to be maintained. The reduction mentioned will not apply to Indentured apprentices unless their rate is stated in the indenture to rise and fall with the journeymen's rate.

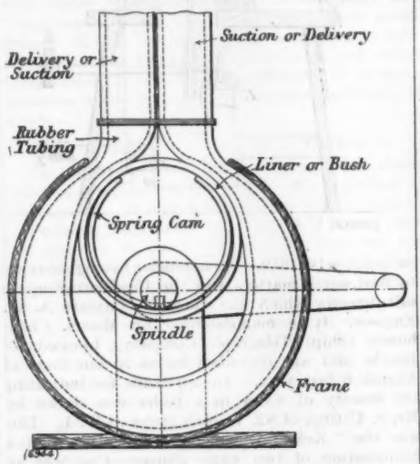
The twenty-second annual report, for 1921, of the General Federation of Trade Unions, states that the aggregate membership is 1,583,058, as against 1,480,108 in 1920 and 711,994 in 1911. The income for 1921 in contributions and entrance fees was 100,895*l.*, and 6,066*l.* from other sources; this is the first time in the history of the federation that the income has exceeded 100,000*l.* The total expenditure was 51,893*l.* The reserve fund now stands at 175,461*l.*

A VALVELESS PUMP.

To the Editor of Engineering.

SIR,—With reference to Mr. Bennett's pump, and the short description given in the current issue of ENGINEERING, page 771, might I mention that some months ago I improvised a very similar pump, the prototype and experimental idea of a recent application for Patent.

My original idea consisted of a short length of rubber tubing curved round so that the two ends formed suction and delivery and the whole inserted in a wooden framing. A spindle mounted in the frame carried a spring cam



on which was mounted a thin bush—originally a serviette ring. As the cam revolved, the bush pressed the tubing, thus giving the "milking" action, in place of Mr. Bennett's cross bar and rotors.

The sketch shows the arrangement.

The development of this principle has resolved into a flexible rubber (or leather) band suitably water sealed on its width, taking the place of the tubing, also a cast-iron or gunmetal casing with suction and delivery branches, the spring cam and bush being retained. There are no valves.

Yours faithfully,
P. H. SUMNER, Captain.

"Thorlands," Farnham Lane, Haslemere, Surrey,
June 27, 1921.

THE PROPORTIONS OF CRANKSHAFTS FOR PETROL MOTORS.

To the Editor of Engineering.

SIR,—With reference to your reply to my letter published on page 785 of your issue of June 24, I am sorry that the writer of the article has not gone further into the questions as requested, but I beg to make the following comments:

What are the ordinary engineering formulæ for obtaining the distortions or deflections in crankshafts which will deal with actual length of bearings, short strokes in relation to diameter of shafts and crankpins, fillets, &c.?

How can crankshaft, Fig. 1 in your issue of May 27 (page 639) be a four bearing shaft when there are no bearings between Nos. 3 and 4 cranks, as stated in the article, and there are no shaft portions between Nos. 2 and 3 crankpins?

Why should rules for shaft diameters be dependent on different engine makers' practice as long as there are ordinary engineering formulæ for obtaining the stresses and deflections in the various parts of the shaft?

The last question has also been evaded, and this is again disappointing, as many high speed petrol engines are direct coupled to electrical generators.

Yours faithfully,
T. MOHN.

10, Rushford-avenue, Levenshulme, Manchester,
June 27, 1921.

A copy of this letter was submitted to the writer of the original article, and he replies:

With reference to above:—(1) The question at issue is simply the relative strength and stiffness of the webs of a shaft and the journals. Formulæ for calculating these can be found in most engineering text-books.

(2) The shaft shown in Fig. 1 has a bearing between No. 1 and No. 2 cranks, another between No. 3 and No. 4. These with two end bearings make four. An inspection of the figure will show this.

(3) There is no reason why "rules for shaft diameters should be dependent on different makers' practice as long as there are ordinary engineering formulæ for obtaining the stresses and deflections in the various parts of the shaft." The object of the article was to point out that the proportions of the webs in certain petrol engines were very different from those of crankshafts as used by experienced marine, stationary and other engineers who make careful calculation of their stresses, and that there did not appear to be any justification for this great departure. If Mr. Mohn considers that the very thin webs shown in the figures are better than ones of ordinary engineering proportions it would be very interesting to have reasons and particulars.

The actual calculations for the size of shaft and webs for any particular engine are outside the scope of the article and in a really high-speed engine are so complicated that it is better probably to trust to direct experience. After all, engineering calculations are only the result of experience, and there has now been a great deal of direct experience in petrol engines.

It may be mentioned that in petrol engines as used in motor vehicles broken crankshafts are not very uncommon, and the shafts in this case usually break through the web.

"THE WRITER OF THE ARTICLE."

THE BUILDING OF AIRSHIPS.

To the Editor of Engineering.

SIR,—About two years ago I had the privilege of taking part in some correspondence in your columns on this subject. In showing that up to that time nothing had been accomplished which gave the remotest indication of any possible commercial future for airships, I pointed out that one of the insuperable obstacles to any such development was the necessity for maintaining a large "landing party" of some 600 men at every port of call.

In answer to my argument it was claimed that the employment of "mooring masts" would obviate this, and enable an airship to be safely landed by a very small number of men. It is now somewhat disconcerting to learn of the accident which happened to "R. 36" the other day, when attempting to pick up her moorings at Pulham. One naturally wonders what would have occurred in the event of neither landing party nor shed having been available. It would be interesting to know whether the landing party had already been paraded, previous to the airship's arrival.

The question finally arises whether, under the circumstances, the Authorities are justified in going to the expense of executing the necessary repairs—even if such repairs be possible without very considerable reconstruction—for putting the airship in flying condition again.

Yours faithfully,
London, June 27, 1921. CECIL LIGHTFOOT.

THE CONTROL OF INTERNAL-COMBUSTION ENGINES.

To the Editor of Engineering.

SIR,—In your issue of June 3, I notice a letter from Mr. McIntosh on the above subject, which has already been the cause of considerable correspondence in *The Automobile Engineer*. In looking through this correspondence I note that Mr. McIntosh did not reply to the last letter from "AMIAE," and it would appear from this that the Ferro Marine Engine Company, of which Mr. McIntosh was chief designer, did not use Mr. McIntosh's patented system of control (Patent 1, 113, 456) for their two cycle engines.

It would therefore be interesting to know on what grounds Mr. McIntosh has based his theory, which apparently has not been applied in practice. If this system of control has been thoroughly tested, will Mr. McIntosh kindly supply some of the test figures for publication in these columns?

Yours faithfully,
D. P. MUIRHEAD.

24, Kilmailing-road, Cathcart, Glasgow,
June 24, 1921.

THE SCHIMIZU-WILSON APPARATUS.

To the Editor of Engineering.

SIR,—In reference to Mr. Craig's letter of the 13th, and my letter of the 10th inst., it appears to me that Mr. Craig has not studied or read my paper before the Iron and Steel Institute of May this year, otherwise he would have a much clearer idea of my letter referred to above.

While Mr. Craig may have used such an apparatus as described 30 years ago, yet I do claim to be the first to adapt this principle to the cleaning of blast furnace gases.

I am, Sir, Yours, &c.,
S. H. FOWLES,
A.M.Inst.E.E., A.M.I.Mech.E.

13, Croft-terrace, Jarrow-on-Tyne, June 27, 1921.

BENEVOLENT FUND, INSTITUTION OF ELECTRICAL ENGINEERS.—We are informed that the offer of Mr. N. M. Hughman, of Bombay, to give a donation of 250*l.* to this fund on condition that 19 similar amounts were contributed by June 30, has been extended by him to December 31, 1921.

NOTES FROM SOUTH YORKSHIRE.

SHEFFIELD, Wednesday.

Iron and Steel.—Recovery in manufacturing operations will necessarily be slow. In many sections orders were badly wanted before the coal strike commenced. That position, of course, has not improved. Prospects in some of the engineering branches are fairly bright. Substantial arrears of orders await execution in mining and textile machinery. There is also evidence of considerable expansion in machine tools for export. Wagon and locomotive works have booked sufficient business to keep them fully occupied from two to three months ahead. Competition is exceptionally keen, however, in railway springs. Wage reductions are being pressed to prevent a general suspension of operations. Makers of heavy castings for marine and general engineering purposes are in a poor position. The operation of exchange differences, coupled with the effect of the supply of cheaper fuel to foreign makers, gives the Belgian establishments a pull on the market which no ordinary works economy locally can fully counteract. Makers of steel-works plant are looking to brighter times ahead, and have extended equipment for output. One of the latest orders booked is for a continuous Morgan Skelp mill. There is no sign of improvement in the crucible steel trade. A considerable tonnage of ferro alloys is available at cheap rates, but users do not seem inclined to renew stocks. The outlook in the steel-making section is the reverse of rosy. Even at the latest reduction of 3*l.* per ton, local makers are badly out-quoted by German and Belgian producers. Yorkshire "crown" iron bars have been marked down to 16*l.* per ton, and bright drawn steel to 20*l.* The lighter trades show weak patches, but an early revival is anticipated in files, saws and hand tools.

South Yorkshire Coal Trade.—On the whole, pits in the South Yorkshire area have not suffered severely from the effects of the coal stoppage, but falls of roof are sufficiently extensive to prevent normal output for seven to fourteen days ahead. At several of the best situated collieries only about one-eighth of the men engaged have been able to resume. Both collieries and merchants are deluged with orders. Preferential treatment in the matter of supply is being given to public utility concerns. A fair tonnage is arriving in the manufacturing areas. Householders are eager to refill their cellars, though probably by the time deliveries are made, prices will have advanced 2*s.* to 2*s.* 6*d.* a ton. The demand for coke for steam-raising purposes in conjoint use with coal, has fallen off. Blast furnaces, which are badly placed for orders, have practically suspended buying. Quotations:—Best branch handpicked, 37*s.* 2*d.* to 38*s.* 2*d.*; Barnsley best Silkstone, 37*s.* 2*d.* to 37*s.* 8*d.*; Derbyshire best brights 35*s.* 2*d.* to 36*s.* 2*d.*; Derbyshire house coal, 32*s.* 8*d.* to 33*s.* 2*d.*; Derbyshire best large nuts, 32*s.* 8*d.* to 33*s.* 8*d.*; Derbyshire small nuts, 31*s.* 8*d.* to 32*s.* 8*d.*; Yorkshire hards, 32*s.* 8*d.* to 33*s.* 8*d.*; Derbyshire hards, 32*s.* 8*d.* to 33*s.* 8*d.*; rough slacks, 23*s.* 2*d.* to 24*s.* 2*d.*; nutty slacks, 22*s.* 2*d.* to 23*s.* 2*d.*; smalls, 18*s.* 2*d.* to 19*s.* 2*d.*

NOTES FROM CLEVELAND AND THE NORTHERN COUNTIES.

MIDDLESBROUGH, Wednesday.

The Cleveland Iron Trade.—Business in Cleveland pig-iron continues very quiet. Producers are not likely to re-start idle blast furnaces until working expenses have been materially lowered by much cheaper coke coming on the market. The better qualities of Cleveland iron are now exceedingly scarce, and the stock threatens to be cleared out altogether before long. Inferior grades of pig-iron, however, are abundant, and makers are keen to sell from their still heavy stocks. There is no foreign business passing in Cleveland pig-iron. To home customers, No. 1 is 140*s.*, and No. 3 and No. 4 foundry are each put at 135*s.*, and, indeed it is almost impossible to purchase unless by taking an equal quantity of each of these qualities. No. 4 forge and mottled are each 117*s.* 6*d.*, and white is 115*s.*

Hematite.—Supply of East Coast hematite is quite plentiful, and sales are not easily arranged. Producers adhere to their minimum for home purposes of 160*s.* for Nos. 1, 2 and 3, but consumers are reluctant to pay that figure. Sellers are under no restriction as to charge for foreign trade, and many firms are anxious to dispose of mixed Nos. for abroad at 140*s.*, but their efforts to sell meet with little success.

Manufactured Iron and Steel.—Little new is ascertainable concerning finished iron and steel. With prices still too high to suit customers, and foreign competition keen, new orders are difficult to secure. Manufacturers, however, have to turn out a good deal of material against contracts already made. Among the principal market rates are: Common iron bars, 16*l.*; steel billets, 14*l.* 10*s.* to 15*l.*; steel boiler plates, 21*l.*; steel ship, bridge and tank plates, 15*l.*; steel angles and joists, 14*l.* 10*s.*; heavy steel rails, 14*l.*; fishplates and sleepers, 19*l.*; black sheets, 19*l.* 10*s.* and corrugated galvanised sheets, 24*l.*

Shipments of Iron and Steel.—The total shipments of iron and steel from the port of Middlesbrough during June reached only 15,812 tons, of which 10,197 tons were pig-iron, 2,024 tons manufactured iron, and 3,591 tons steel. Shipments of pig-iron to foreign ports amounted to 8,922 tons, whilst manufactured iron sent abroad reached only 1,092 tons, and steel 3,561 tons. Clearances coastwise were 1,275 tons of pig-iron, 932 tons of manufactured iron and 30 tons of steel. France, with an import of 3,155 tons was the largest receiver of pig-iron, Belgium being second with 3,042 tons, and Scotland third with 780 tons. The best customers for both manufactured iron and steel were the Straits Settlements with imports amounting to 668 tons of the former, and 1,087 tons of the latter. Among other principal buyers of steel were: China, 860 tons; India, 78 tons; and Cape Colony, 558 tons.

Imports of Iron and Steel.—Monthly statistics, issued by the Tees Conservancy Commission, of iron and steel imported to the Tees from Holland, Belgium and France show a marked increase as compared with pre-war periods in regard to pig-iron. According to the returns 17,241 tons were imported during the past eight months, as compared with 1,057 tons and 218 tons for the corresponding periods of 1912–13 and 1913–14, respectively. Imports of billets, blooms, slabs, &c., for the past eight months reached 17,201 tons, as compared with 19,844 tons for the same period in 1912–13, and 30,307 tons in 1913–14; and plates, bars, angles, rails, sheets, joists, &c., unloaded for the eight months ending June last amounted to 16,641 tons, as compared with 17,508 tons in 1912–13, and 17,419 tons in 1913–14.

NOTES FROM THE SOUTH-WEST.

CARDIFF, Wednesday.

The Coal Markets.—The buyers are concentrating their attention upon securing their supplies of coal during July, and for deliveries that month the supply certainly falls below the demand. This was especially the case to-day, when prices appreciably hardened, and for best large 47*s.* 6*d.* was firmly quoted, while smalls could not be obtained under 25*s.*, with intermediate grades at corresponding prices, and at these levels several transactions took place. Generally speaking, the collieries are working as well as can be expected after a stoppage extending over three months. Here and there local disputes have delayed a prompt start being made. The most important of the collieries which are still idle are those of the Ebbw Vale Company, who employ about 10,000 men. Every delay in re-starting naturally has an adverse effect on outputs, but some quantities have already reached the ports for shipment. While, therefore, there is for the moment a decided shortage, buyers are holding off as regards forward or even August deliveries in the expectation that in the meantime production may be on such a scale as to result in a reduction of prices. It is, however, impossible to predict with any degree of confidence as to whether this will be the case ultimately as it will take some time before normal conditions can be restored.

Iron and Steel Trades.—As a natural sequel to the resumption of work at the coal mines, there has been a movement in the direction of renewed activities in the metallurgical centres, and a few works have been re-started, and the furnaces at the Port Talbot steel works were re-lit to-day. At the same time manufacturers are none too sanguine, and it is asserted that the tin-plate industry, at all events, cannot be restored to a state of prosperity until the price of coal and other costs are materially reduced in order to enable makers to compete successfully with foreign rivals. In the circumstances, therefore, the prospect in the immediate future is none too promising, but the fact that a start has been made here and there is encouraging, and if only the workmen themselves are made to realise the actualities of the situation no difficulty in the way need be regarded as insurmountable.

THE INSTITUTION OF ELECTRICAL ENGINEERS.—On Thursday, 30th ult., this Institution held its annual conversazione at the Natural History Museum, South Kensington, when some 1,600 guests were received by the president (Mr. Ll. B. Atkinson) and Mrs. Atkinson. A deputation of the American engineers now in this country was also present, and Mr. Atkinson welcomed them with very warm words in recognition of their attainments and activities. Mr. Ambrose Swasey, chairman of the deputation, and Dr. F. B. Jewett, Vice-President of the American Institute of Electrical Engineers, responded, expressing their delight at having the opportunity of bearing testimony to the fraternal feelings which animated engineers on both sides of the Atlantic.

THE WEAR AND BURSTING OF COOLING COILS OF AIR COMPRESSORS.—At the June meeting of the Diesel Engine Users' Association the subject of "Wear and Bursting of Cooling Coils of Air Compressors" and safety devices in connection therewith was discussed. The subject had been particularly brought to the notice of the committee as a consequence of a communication received from a member abroad referring to the working of Diesel engine plant under tropical conditions, and to an accident which had occurred due to the bursting of a cooling coil. The president, Mr. C. O. Milton, gave a very interesting account of investigations which he had carried out to endeavour to ascertain the cause of the wear of cooling coils, and as to whether this was brought about by corrosion or erosion or both. He gave data of the actual wear of cooling coils at different points of their length after various periods of running and at varying loads, and he explained the methods he had used for ascertaining the wear by periodic weighing of the coils and by an electrical method of determining the variation in resistance of a unit length of the coil at different points. He emphasized the importance of paying attention to the draining of compressors between the stages of compression and of restricting the use of lubricating oil in the compressors to the strict minimum consistent with proper lubrication. His investigations also showed the importance of taking into account the engine load factor and atmospheric conditions. In the course of the discussion it was made evident that the question of atmospheric humidity was of material importance in connection with the wear of compressor cooling coils.

NOTICES OF MEETINGS.

THE ROYAL SOCIETY OF ARTS.—Thursday, July 14, at 8 p.m. "Paints, Painting and Painters, with reference to Technical Problems, Public Interests and Health," by Professor Henry E. Armstrong, Ph.D., LL.D., D.Sc., F.R.S., and Mr. A. C. Klein.

THE INSTITUTION OF PRODUCTION ENGINEERS.—Friday, July 15, at 7.30 p.m., General Meeting at the Institution of Mechanical Engineers, Storey's Gate, S.W. 1, when all those who are interested in matters appertaining to production are invited to attend. Mr. Max Lawrence, M.I.M.E., M.I.A.E., will read a paper on "Production and the Engineer."

NOTES FROM THE NORTH.

GLASGOW, Wednesday.

The State of Trade.—With the coal strike over and the miners now back at work a better feeling prevails throughout the country, but of course there is very little coal available yet, and what is on offer is much too dear for ordinary industrial purposes. Quantity at a low price is what is wanted, and sellers quite realise this, but until a decent output is forthcoming supplies are bound to be dear. Establishments everywhere have been closed so long now that many managements seem quite determined not to light up until they are assured of satisfactory supplies of fuel at fairly moderate rates. The result of this will be that few works will be set going until after the stipulated holiday period, and many concerns will thus not commence operations until about the last week of this month, or the beginning of August. Generally speaking, there is a great absence of business, and not only that but inquiries are very poor all round. The holiday season is now on, and works and shipyards in Port Glasgow and Greenock district are closed down this week, while the holiday period in Glasgow neighbourhood commences about the middle of next week.

Scottish Steel Trade.—There is little fresh to report in connection with the Scottish steel trade this week, and as no quantity of fuel can yet be had, only one or two works have made a start, and it is doubtful if many producers will actually commence operations in their rolling mills in earnest until towards the end of this month. The recent reduction in prices has not brought out much business and as order books are far from being well filled there is indeed little to commence on, even should managements be inclined to open their works. A certain number of inquiries are now going around, but many are only considered as feelers, and may not result in business. Things are in such a peculiar position now that great caution is being exercised, as the Continental producer, blessed with cheap fuel, low wages, and the exchange which in cases is in his favour, can undersell us to a considerable extent.

Scottish Pig-Iron Trade.—Preparations have begun in the way of getting the pig-iron furnaces ready for a start in the near future, but in most instances the buyer and seller of coal cannot see eye to eye. As has been stated repeatedly, cheap pig-iron is a necessity if the general trade of the country is to recover, and that means a much lower price for coal than has been named this week by sellers. This is no inducement whatever to the ironmaster to start smelting. The demand for iron is not very heavy yet, but stocks are now low and most qualities of foundry iron are off the market.

Scottish Shipbuilding.—The shipbuilding returns for the past month place it third on the list for the half-year, and although the total was only 25 vessels, amounting to 42,651 tons, these figures must be considered fairly satisfactory when the many difficulties occasioned by the miners' strike are remembered. From the different districts the output was as follows:—

	Vessels.	Tons.
The Clyde	16	40,371
The Forth	2	656
The Tay	1	850
The Dee and Moray Firth ...	6	774
Totals	25	42,651

The Clyde figures are the lowest for the month of June for several years back, and would have showed up rather badly had it not been for the turbine steamer Largs Bay, 13,500 tons, launched from Messrs. Beardmore's yard at Dalmuir, for the Australian Commonwealth Government Line of steamers. The Clyde total for the six months now amounts to 118 vessels of 235,800 tons, which is the lowest half-year's output for the past eleven years, excluding the war years. It is fully 51,000 tons under the figure for the same period of last year, and less by over 112,600 tons than the record year of 1913, when the six months' output was 348,476 tons. The booking of new contracts is still very poor, and despite the fact that both wages and material are lower, owners are still unwilling to place new orders at the prices which builders are forced to name. As things are now the prospects for the remainder of the year are not very promising, but it is to be hoped that a turn for the better may take place in the near future.

THE LONDON IRON AND STEEL EXCHANGE, LIMITED.—The secretary states in his report for last Tuesday, that there seems little likelihood of the British blast furnaces and billet rolling mills being placed in commission again until the costs of production have been materially reduced or market values have been advanced considerably. French and Belgian iron and steel prices are irregular, but as a rule considerably above the German figures, although a good many pounds below the prices quoted by British makers.

AUTOMATIC MACHINE FOR GRADING STEEL BALLS.

CONSTRUCTED BY MESSRS. RUDGE-WHITWORTH, LIMITED, ENGINEERS, BIRMINGHAM.

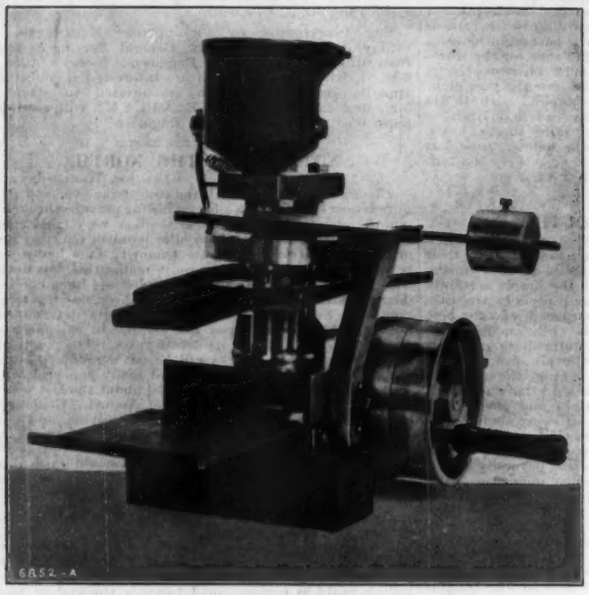


FIG. 1.

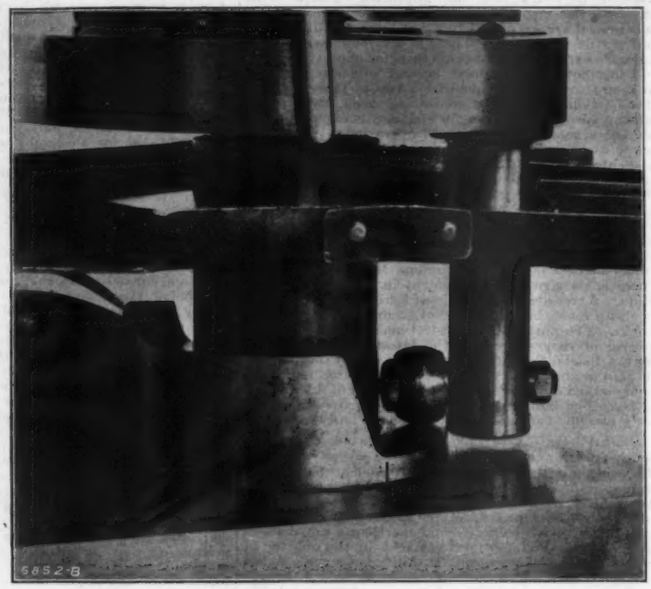


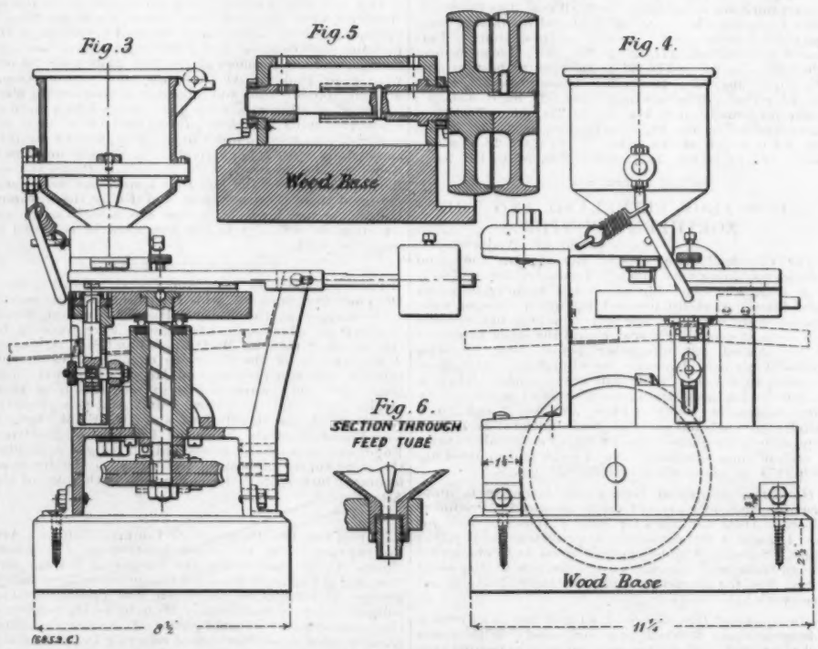
FIG. 2.

WE have recently described the manufacture of steel balls in these columns and we gave instances at the time to show the extraordinary accuracy with which such balls are produced. It will be remembered that the usual guarantee of the makers is that no ball shall vary from the nominal size by more than one ten-thousandth of an inch, but while this applies to commercial balls sold in bulk, the makers themselves grade balls to something like one fifty-thousandth of an inch, and use balls all of the same graded size in any particular bearing.

The grading of steel balls is one of the processes in which mechanical ingenuity has sought to eliminate the human element. An apparent solution of the problem would be to allow the balls to run down an inclined track formed by the slightly divergent edges of steel bars, so that they would fall through at different points according to size. This would be delightfully simple if it would work, but in practice it is found that only a very coarse grading can be accomplished by such a method. When the balls are about to fall through, they are supported practically by diametrically opposite points, about which they spin for a long time and neither fall through nor roll along. As this method of grading was found unsatisfactory, Messrs. Rudge-Whitworth, Limited, who manufacture steel balls and bearings on a very large scale at their works at Sparkhill, Birmingham, set themselves to devise a mechanical method of grading which should embody the principle which had proved successful when accomplished by hand.

The machine which was designed and patented by the firm for grading balls is illustrated in Figs. 1 to 6, on this page. It works entirely automatically. The balls to be graded are placed in the hopper at the top of the machine, from which they descend one by one through the central feed tube at the bottom of the hopper. They are continually agitated in the hopper by a finger piece on a cross-shaft, which is seen in Fig. 3. Fig. 6 shows the agitating finger and the feed tube. The balls descend on to a revolving plate, where they are retained until a gauging ring carried by the plate registers with the mouth of the feed tube and allows the ball to fall into position for gauging. The revolving plate carries the ball in the gauging ring underneath a pivoted pressure plate with an adjustable counterbalance weight, which can be seen in Figs. 1 and 3. This plate has a projecting circular track on its lower face, exactly corresponding with the path of the ball and furnished with inclined faces at each end to allow the ball to pass under and away from it without shock.

It will be obvious that the pressure exerted by the plate on the ball will vary with the difference of position of the ball beneath it, the initial pressure being slight and increasing gradually as the ball approaches the fulcrum. At some point in its path, depending upon the size of the ball, the pressure will be great enough to push the latter through the gauging ring, but if the ball is too large to be pushed through by the maximum pressure, it will be carried round clear of the plate. Immediately under the revolving plate, is a tray divided into four or more comparatively narrow channels, into one of which the ball will fall, depending on the distance it is carried before being pushed through the gauging ring. These channels lead the graded balls away to their respective boxes.



In the event of a ball being too large to be pressed through the gauging ring by the influence of the pressure plate, as adjusted for the size of the ball being handled, it is carried clear of this plate by the continued action of the revolving plate and ejected from the gauging ring by a plunger. The plunger is adjusted vertically for different sizes of balls by a screw, and is controlled in its action by the roller running on the circular cam shown in Fig. 2. The point of ejection is arranged as soon as possible after the ball escapes from the pressure plate, so that the gauging ring may be empty and therefore ready to receive another ball as it comes under the feed tube.

The face of the cam is so designed that when the ball is about to fall into the gauging ring out of the feed tube, the plunger is raised to receive it. Any momentum, therefore, which the ball may attain in falling, is taken on the plunger and not on the gauging ring where it would affect the accuracy of the machine. The plunger remains in this raised position until the ball has engaged with, and partially raised, the pressure plate, when it gently falls and allows the weight of the ball and the pressure of the plate to be taken by the gauging ring. The mechanical details of the machine will be obvious from the figures. Motion is imparted to the revolving plate by means of a worm and worm wheel, actuated by a belt on the pulley shown, and the agitator provided in the hopper to ensure delivery of the balls is worked by a projecting pin on the revolving plate.

DETAILS OF HORIZONTAL BORING

CONSTRUCTED BY MESSRS. CUNLIFFE AND

(For Descri, see Page

Fig. 395

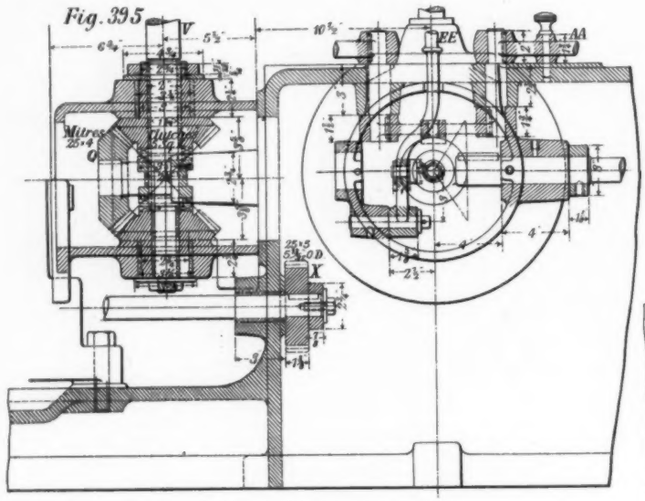


Fig. 396.

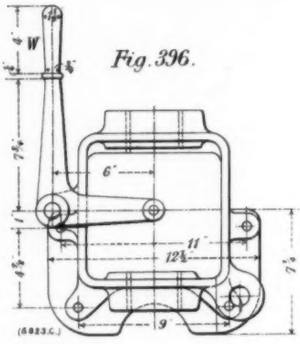
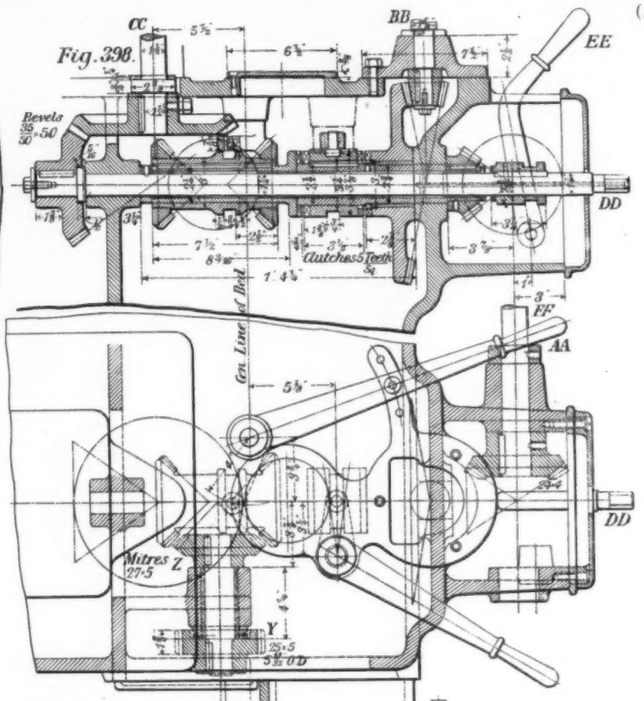


Fig. 398.



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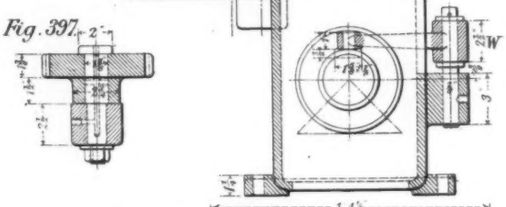


Fig. 399

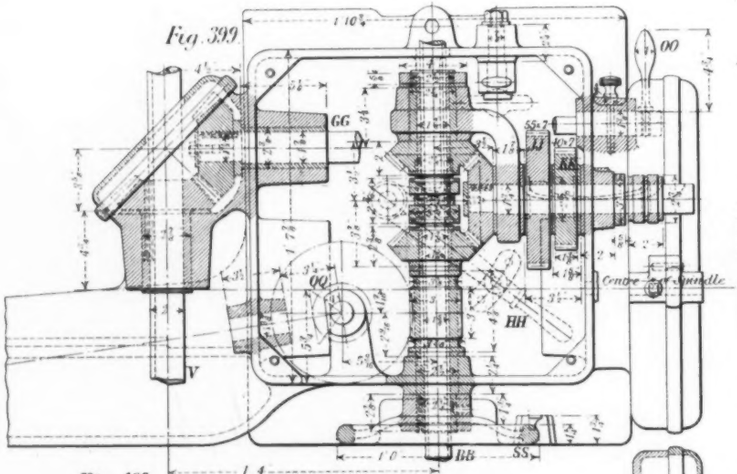


Fig. 401.

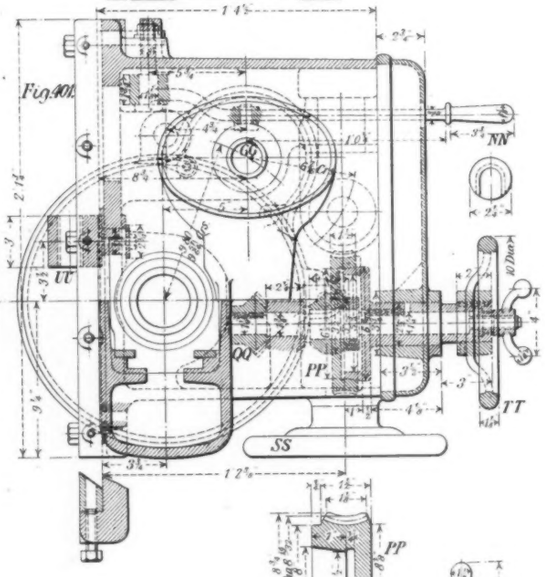
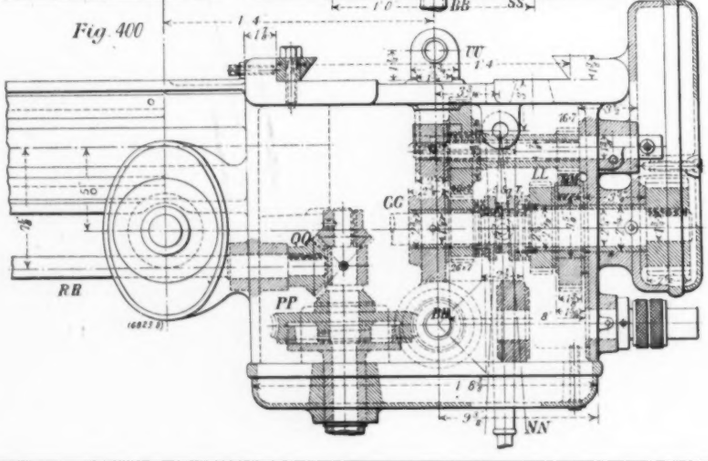


Fig. 400



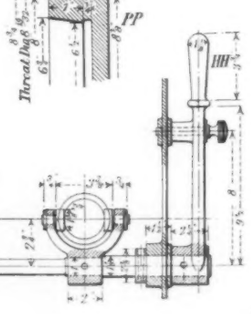
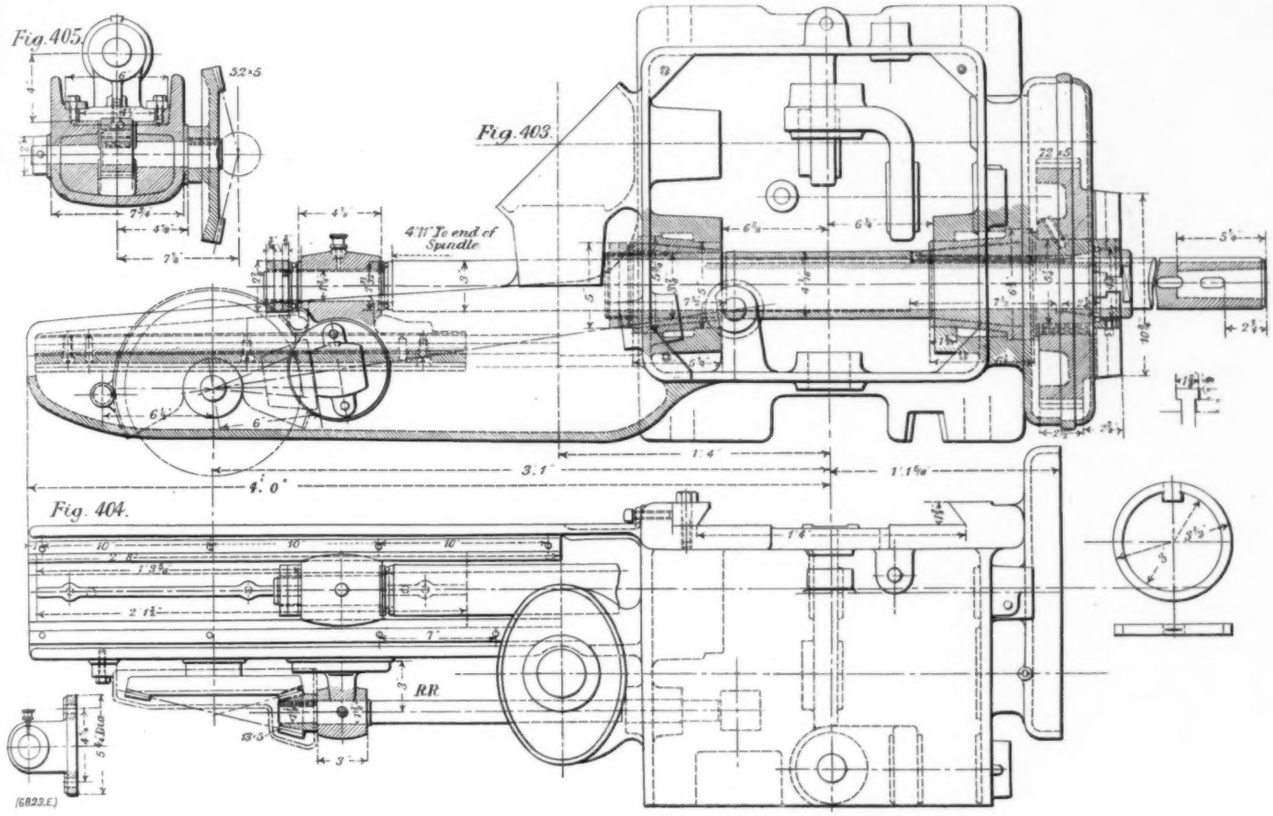


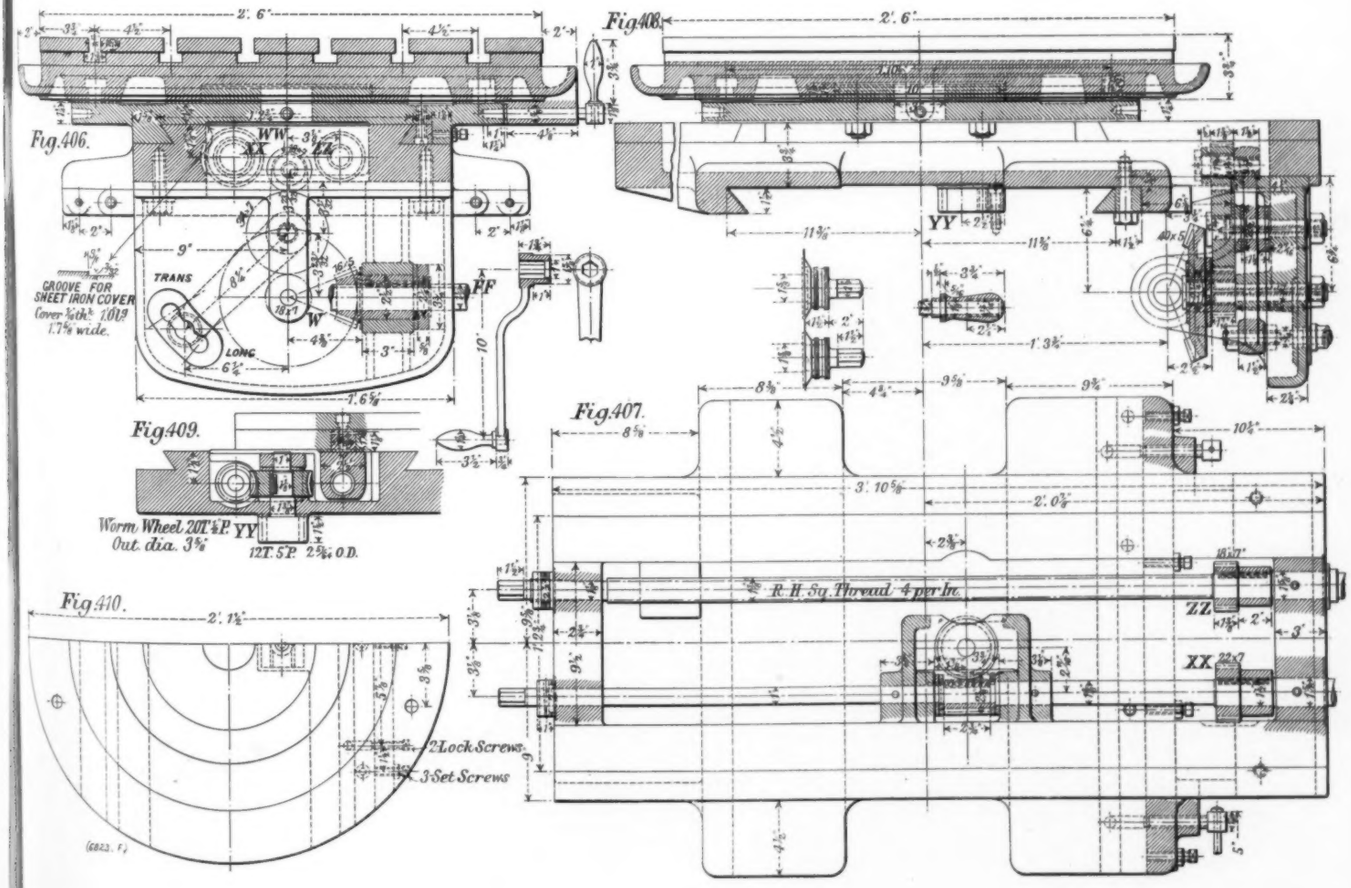
Fig. 402.

DRILLING AND MILLING MACHINE.

OM, LIMITED, ENGINEERS, MANCHESTER.

see Page 33.)





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Advertisements intended for insertion in the current week's issue must be delivered not later than First Post on Thursday. In consequence of the necessity for going to press early with a portion of the edition, alterations for standing advertisements should be received on the Friday previous to the day of publication.

The charge for advertisements classified under the Headings of Appointments Open, Situations Wanted, Tenders, &c., is four shillings for the first four lines or under, and one shilling per line up to one inch. The line averages seven words. When an advertisement measures an inch or more the charge is 12s. per inch. Payment must accompany all orders for single advertisements, otherwise their insertion cannot be guaranteed. Terms for displayed advertisements on the wrapper and on the inside pages may be obtained on application. The pages are 12 in. deep and 9 in. wide, divisible into four columns of 2⅛ in. in width. Serial advertisements will be inserted with all practicable regularity, but absolute regularity cannot be guaranteed.

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TELEPHONE NUMBERS—3663 and 8598 GERRARD.

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With a Two-Page Plate of the DETAILS OF HORIZONTAL BORING, DRILLING AND MILLING MACHINE.

NOTICE.

The Publisher begs to announce that on the 1st of July the price of "ENGINEERING" was reduced to

1s. per copy.

NOTICES OF MEETINGS.

Notices of Meetings to take place during the present and next week will be found on page 59.

ENGINEERING.

FRIDAY, JULY 8, 1921.

THE PRINCIPLE OF THE COAL SETTLEMENT.

THE statement issued last week by the Board of Trade setting forth the terms upon which peace has at last been concluded in the coal-mining industry is a document of first-class importance. We do not say this merely because it marks the termination of a dispute which has brought disastrous loss upon the country, but rather because it imports into the settlement a principle which is different from anything previously existing in the relationship between capital and labour, and one which indeed may have the most far-reaching effects upon the whole industrial system. It is rather surprising that the agreement has provoked so little comment. The reason, no doubt, lies partly in the fact that every one has long been weary of and disgusted with the whole business, and with the ineptitude with which it has been handled by the leaders on both sides. But the nature of the document itself largely explains the silence. One of the leading morning journals entitled it "A Precise Charter for the Men," although it is anything but precise with regard to important points of detail. It is, moreover, formulated in such a way that we doubt whether one in a thousand of the working miners whom it so intimately concerns, could ever make out for himself what it really means. It will be remembered that after the negotiations with the Government had lasted several weeks, Mr. Lloyd George confessed himself unable to understand the offer of the employers, and if the latter was worded as ineffectively as the present agreement we are not surprised. Surely if ever there was a case in which straightforward expression in simple English was required, this was one.

Such comment as has appeared concerning the settlement has been mainly directed at the dangerous precedent of the Government subsidy. The much-harassed ordinary citizen, struggling to make both ends meet at his own trade, does not see why he should be compelled to purchase peace in a quarrel to which he was no party by contributing to pay 10,000,000*l.* to an industry, which he feels to have earned no special claim on his charity. As to the rest of the agreement, he probably has not tried to understand it, regarding the terms as a matter of little interest to anyone not directly concerned with the production of coal. Yet, as we have already indicated, it is worthy of careful study, because it admits a novel principle into the economics of industry which may be applied far beyond the confines of the present case.

We do not propose to discuss the settlement as it affects the coal trade. It is now an accomplished fact, and we can only hope and trust that it will prove an equitable and satisfactory solution for the troubles of that industry. Our object in referring to it is to examine those features of it which may at some future time be brought forward as a precedent when wage disputes occur in other trades. The underlying idea is that, subject to a certain minimum rate of earnings, the workman shall participate in the profits of the industry by an automatic periodic adjustment of his wages in accordance with those profits. This is unquestionably sound in principle. It must not for a moment be confused with any method of regulating wages according to the selling price of the product. Such methods have of course been tried for many years, but they suffer from the inherent fault that high prices may coincide, as at present, with periods of extreme depression. Schemes of this kind, moreover, are only applicable to a few of the simpler industries in which the product commands a definite market price, and they involve the vicious idea that it is to the workman's benefit to make the costs of production high. If, on the other hand, the workmen's wages are regulated by the profits of the industry, the men's interests are co-ordinated with those of the employers, and they have, equally with the latter, an inducement to promote economical production and to utilise the most efficient methods and machines for this purpose.

The machinery by which it is possible to regulate wages in accordance with the profits of an industry, and the methods by which the profits shall be assessed, both constitute problems of extreme difficulty. It is clear that the profits of an industry taken as a whole can only be ascertained by obtaining financial returns, drawn up on a standard form, from every firm engaged in the industry. This is what is presumably to be done in the coal trade, and when we mention that there are something like 4,000 coal pits in Great Britain, hundreds of which employ a total of less than a dozen men each, the difficulties of the job will be apparent. But if this can be done in the coal trade it is equally practicable in the engineering, or other trades, particularly if the districts are not of unwieldy size. The gist of the coal agreement is that the rate of wages to be paid during any period shall be determined by the proceeds of the industry during the previous period, and shall be expressed as a percentage of a certain nominal basis rate fixed for each district. So far, again, there is nothing provided for which is fundamentally incompatible with the conditions of the engineering trade generally.

The coal agreement is quite needlessly complicated by the introduction of a fiction called the "standard wage," which is neither the basic wage, nor the minimum wage, nor the actual wage of the miner. For the purpose of discussing the nature of the agreement, and its possible application to other trades, we will assume that standard wage, basic wage and minimum wage are equivalent terms, all denoting a rate of payment agreed upon between employers and trade unions, as the level below which wages shall not fall. With this understanding, which we would repeat, does not apply to the coal agreement, the actual wages rate for any district during any period would be determined as follows. First of all the men would receive the standard rate, and, over and above this there would be paid to them in wages, 83 per cent. of the surplus of the proceeds of the industry during the previous period. The divisible surplus would be arrived at by adding together the aggregates of the cost of the standard wages, the costs of production other than wages, and a sum known as standard profits, equal to 17 per cent. of the standard wages, and subtracting the total so obtained from the whole proceeds of the industry during the period concerned.

It cannot be made too clear that the percentages we have mentioned are simply and solely figures to be used in calculating wages and in no way limit the profit which any particular company may make. Every firm in the district will be notified, at the commencement of a period, of the rate of wages which is to be paid for that period, and subject to the payment of these wages the firm may make what profits it can.

Every firm in a district would have to make the necessary returns periodically to the District Board, who would calculate the aggregates and determine, in accordance with the above rules, the actual wage-rate which should apply to the district during the next period.

With regard to the returns to be made by individual firms, the first, namely, the calculated amount of standard wages, would present no difficulty, and the third item is, of course, a matter of simple arithmetic. It is with the second item—costs of production other than wages—that there is room for much honest difference of opinion as to what should be included. In the case of the coal-mining settlement, the decision is to be left to the District Boards, who will no doubt give a ruling applicable to that particular industry. Presumably, as applied to general engineering, the item would include all expenditure other than wages, chargeable to revenue account, thus covering debenture interest, materials

for production and maintenance, freights, office expenses, salaries, taxation, &c. The last item, namely, the whole proceeds of the industry, would apparently represent the gross receipts of the firm during the period in question. With the various items once clearly defined, there would be no special difficulty in making the returns, if the books were kept in anything like the proper manner, and if coal mines employing, say, a total of six men, have to send in the particulars, it cannot be said to be impossible for a small engineering works to do the same. Whether engineering firms would care to disclose so much of their business to the members of the District Board, is, of course, another matter, but any corresponding reluctance in the case of the coal-owners has apparently been got over. Moreover it is certain that a policy of placing the actual economic facts of an industry before the responsible leaders of the workmen, is the surest way to promote industrial peace.

But quite apart from the question as to whether any scheme on the lines of the coal agreement would be technically workable in the engineering trades, one has also to consider its probable effects on the industry. We have seen that it provides the workman with a rate of wages which depends upon the profits that the industry is making, a certain minimum rate being guaranteed to him. His wages do not fluctuate with the fortunes of the particular firm he is working for, but with those of the industry of his district as a whole. Uniformity of rates throughout an area is secured, as at present, with the advantage that wage competition between firms is eliminated, but with the drawback that the extreme effort of the men in any one firm to promote efficiency, is only faintly reflected in the benefit they receive. Only if the scheme is combined with a general system of individual payment by results, will the fullest reward be secured to the most efficient workers, who will then have the satisfaction of knowing that in working hard for themselves they are also working indirectly to raise the wage level of the district.

From the employers' point of view there is nothing resembling any pooling of profits in the scheme. The firm that is b dly managed or inefficient will have to bear the consequences upon its own shoulders, and the well organised business will enjoy its individual prosperity. If a particular firm makes large profits it will keep them for itself, the only effect upon the district being that the general rate of wages will be slightly increased. Similarly when a firm does badly, its misfortune will tend to lower the general district wages. In both cases, of course, the results obtained by any one firm will have only an infinitesimal effect upon wages. Whether the scheme will prove beneficial to any industry or even whether it can be worked without bringing disaster to the industry depends entirely upon whether it will permit of a sufficient return upon capital expended to make it worth while for those who save money to invest it in the business. If it will do this, it appears to provide the best solution yet devised for assuring to the workman a share of the profits which he helps to create. If it will not do so, it will bring about the extinction of the industry, for capital is just as necessary to carry on any manufacturing process as is the presence of manual and brain workers.

A very noticeable feature of the scheme is that there is no provision at all for any minimum return upon capital before the division of the surplus profits. Indeed in the coal agreement the word capital, or its equivalent, is not even mentioned. Whether the payment of interest upon capital has any ethical sanction or not is beside the point, the hard facts are that capital never has been and never can be obtained to build works and to finance contracts unless interest is paid for the use of it. Capital is the savings of the thrifty, and no one will part with his savings and risk their loss without some compensation. The percentages mentioned previously as factors in the calculation of wages are designed to ensure a reasonable return upon capital and one which shall increase, as wages are to do, in accordance with the prosperity of the industry. The figures which we quoted in explaining the scheme may be fair and equitable for the coal trade, but obviously they will need revision to suit the different ratio between capital expenditure and labour employed which is met with in other trades. Provided that the percentages in question are wisely determined, so that capital and labour are both sure of a living wage, and then of a fair division of such surplus proceeds as they jointly may earn, we believe that some such scheme as we have discussed has greater possibilities for good than have ever yet been realised in methods devised for regulating wages. As applied to the coal industry, its working will be watched with the keenest interest by all who are concerned with industrial problems.

LEGAL EFFECTS OF VARIATIONS ON CONTRACT TERMS.

THE past and present condition of the labour market has for some time rendered it practically impossible for any builder or other contractor to undertake work for a fixed sum. In former days, when conditions were fairly steady it was a business proposition to give an estimate, which was not to be exceeded; but no contractor can afford to do this at the present time. The risk is too great. He is compelled to transfer the burden of extra wages and increased cost of materials and transport to the shoulders of the person or persons for whom the work is to be carried out. By what means can the burden be best transferred? If a contract is framed so as to effect this object, what is its legal effect?

These are questions of considerable practical importance. The prevailing idea is that it is sufficient to take some well-known form of contract and attach thereto a clause in some such terms as the following: "The contract sum is based upon the rate of wages cost, of material and transport current on the (*date of contract*). Any increase or decrease thereon to be adjusted at the time or at the final settlement of account, and the contractor shall from time to time supply to the engineer the necessary vouchers, time sheets and all other necessary documents which in the opinion of the engineer are required for this purpose." Sometimes the clause provides that notice of any increase in wages, or in the price of materials shall be duly given to the engineer.

So far as the contractor is concerned there does not appear to be any objection to this clause; but it undoubtedly imposes a great and uncertain liability upon the purchaser or building owner. Indeed, if the would-be purchaser has but limited resources it is difficult to see how he can prudently attach his signature to a contract containing such a clause. It is true that he becomes entitled to any advantage which may accrue from a fall in wages or materials; but he acquires no new right to withdraw from a contract which changed conditions have rendered too burdensome. He can only break his contract upon the usual terms, i.e., those of making good to the contractor all the loss which he may sustain if he is not allowed to complete the contract.

It may be that purchasers who will be content to sign a contract containing a clause in the terms above stated are sufficiently numerous to obviate the necessity of abating its rigour; but there must be a large number of persons who will not sign a contract unless they know, with some approach to accuracy, the amount of money which they will have to pay in order to secure completion. Is it possible to draft a clause which will at once protect the contractor and yet overcome the natural scruples of a would-be purchaser who does not wish to commit himself too deeply?

Something will depend, of course, upon the nature of the work which is to be carried out. In the case of a contract to execute numerous machines or (say) bridges in accordance with a common design, it would be feasible to provide for their erection in batches, reserving to the purchaser the right to suspend operations or terminate the contract after the erection of a certain number. In such circumstances the contract would have to specify (*a*) the date when the contractor would have to commence the erection of each batch; (*b*) the length of notice to be given by the purchaser of his intention to proceed further; and (*c*) the amount of compensation to be paid to the contractor for the forfeiture of his right to complete the work in accordance with the terms of the original contract. This last matter is important, because the contractor who embarks on a large contract must naturally "budget" for the acquisition of a large quantity of materials with which to complete. His lump sum will be based upon the price of those materials as at the date of the contract. If the price subsequently falls he will be the gainer, but if it rises he may be the loser. For the same reasons it is obvious that if the purchaser is to have the right to terminate the contract at particular stages, the contractor should enjoy the corresponding privilege of notifying the purchaser, after certain works have been executed, that he does not intend to proceed.

But let us consider the more difficult case of a contract to erect a particular machine or structure for a lump sum. In such circumstances it is a practical impossibility to frame a clause which shall enable a purchaser to withdraw if he finds that the works are to cost him more than he can afford—practically impossible, that is to say, from the contractor's point of view. No contractor can undertake the erection of works unless it is reasonably certain that he shall be paid for his labour and materials. This for the very good reason that materials built on a man's land become his property and cannot be reclaimed by the contractor. The only provision upon which a purchaser can reasonably insist is that he or his engineer shall be notified as the work proceeds of any increase which has taken place in the cost of labour and materials. For a contractor to sign any contract which gave the purchaser the right to terminate as and when he pleased—subject, say, to payment for work already done by measure and value—would be a very risky proceeding.

It remains to consider the effect, as regards the purchaser, of a clause providing that due notice of any increase in wages or in the cost of materials shall be given to his engineer. Assume that no such notice is given, what is the result? Could the purchaser refuse to pay the increased cost? This is, to say the least, extremely doubtful. Unless it is specifically made a condition precedent to the right to charge extra that notice of the increased charge shall be made within a given time and in a certain way, it is conceived that the purchaser's only claim would be for damages for breach of contract, and the measure of those damages would not necessarily be the increase which he had to pay. For it is to be borne in mind that the purchaser is under agreement to allow the contractor to complete even at the enhanced prices. Again, suppose the engineer duly receives notice but does not pass it on to the purchaser, will the purchaser have any right over against the engineer? He could sue him for negligence, but here again it is extremely difficult to say what the measure of damages would be. At most the purchaser could say: "Had you notified me in time, I could have declared my intention of proceeding no further."

To this the engineer could properly reply: "True, you could have terminated the contract; but that would have been a breach of contract which would involve you in a claim for damages." In these circumstances it is not easy to say what the measure of damages would be against the engineer—even assuming there was an engineer who was so foolish as not to keep his employer duly informed of everything which is likely to add to his burden. Enough has been said to show that the mere addition of a few words to any standard form of contract is scarcely sufficient to properly define the rights of the parties where prices and wages are liable to fluctuation. Some new form of contract appears to be necessary to deal with the various contingencies which may arise.

BRITISH AND GERMAN CLAIMS.—The Board of Trade announce that by an agreemtnt made with the German Clearing Office now awaiting the approval of the Reichstag, the time for lodging claims with the British and German Clearing Offices by their respective nationals under Article 296, Section III, Part X, of the Treaty of Versailles, has been extended to September 30, 1921. No further claims under the above article will be accepted after that date by the Clearing Offices concerned.

INSTITUTION OF MECHANICAL ENGINEERS.

SUMMER MEETING.

THE summer meeting of the above Institution was this year held in London, on Thursday, June 30, and Friday, July 1, and took the form of a Conference, the object of which was to discuss "Means of Improving the Thermal Efficiency of Heat Power Plants." Short papers bearing on the question were read and discussed concurrently in the Library, the Reading Room, the Council Room and the Committee Room of the Institution. There was also, in connection with the Conference, an exhibition of appliances pertaining to boiler-house operation, a notice of which appears elsewhere in this issue. The Conference opened on Thursday, June 30, by a general meeting in the Library, the President, Captain H. Riall Sankey, C.B., C.B.E., R.E. (retired), occupying the chair.

RECEPTION OF AMERICAN ENGINEERS.

The president remarked that his first duty was to extend to the delegation of American engineers a most cordial welcome from the Institution. Members would recall the joint meeting of the Institution and the American Society of Mechanical Engineers at Birmingham in 1910, and he hoped that the friendships then formed would be cemented on the present occasion. The speaker then directed attention to the rapid growth in membership achieved by the American Society of Mechanical Engineers, the numbers having risen from 3,000 in 1910 to 14,000 to-day. In the case of the Institution of Mechanical Engineers the corresponding figures were 6,000 to 8,000. We in England needed to "get busy" in the matter of increasing membership. The American Society of Mechanical Engineers adopted as their motto the words "Service to others," and the speaker commended this motto to the Institution of Mechanical Engineers and to other institutions. To give full effect to that motto, the Federated American Engineering Societies had been formed, and the terms of its preamble were these: "As service to others is the expression of the highest motive to which men respond, and as duty to contribute to public welfare demands the best efforts man can put forth, now therefore the engineering and allied technical societies of the United States of America, through the promotion of the Federated American Engineering Societies, realise the long-cherished ideal of comprehensive organisation, dedicated to the service of the Community, State and Nation."

Captain Sankey took the view that a similar federation should be instituted in this country.

As members were aware, the object of the delegation was to present the John Fritz medal to Sir Robert Hadfield, for his discovery of manganese steel, and this ceremony had already taken place at the Institution of Civil Engineers, Mr. Ambrose Swasey, the chairman of the John Fritz Medal Board, having presented the medal. Mr. Ambrose Swasey was a man of world-wide reputation, and numerous honours had been awarded to him. Many years ago he, with Mr. Warner, had founded the company bearing their names, and the machine tools produced by the firm were known everywhere. Mr. Swasey was the designer and maker of the mountings of the great telescopes of the Lick and Yerkes Observatories, and also more recently of that of the 72 in. reflecting telescope for the Canadian Government. In 1914, upon receipt of a gift from Mr. Swasey, the Engineering Foundation was established for research in the science of engineering and the advancement, in any other manner, of the profession of the engineer. Mr. Swasey's donations now amounted to 500,000 dols. The Council of the Institution had felt that no better opportunity could be found of giving to Mr. Swasey the highest honour in their power to confer. Accordingly the council, at their meeting on June 17, had elected, with acclamation, Mr. Ambrose Swasey as an honorary member of the Institution.

Mr. Ambrose Swasey expressed deep gratification at the honour which had been bestowed upon him by an Institution, the life of which had extended over seventy-five years, an Institution which had for its leaders some of the great men of the past, such as Stephenson, Whitworth, Armstrong, &c. It had been the speaker's privilege to be connected with the Institution over twenty-two years, and he had enjoyed the privilege of occasionally attending its meetings and excursions. He felt that this honour had been conferred upon him not alone as an appreciation of his own work, but of what engineers in America had done; and, further, as an appreciation of the work of the American Society of Mechanical Engineers, of which he was one of the original founders and organisers. The honour which had been bestowed upon him he regarded as of the greatest worth.

Mr. Charles F. Rand expressed the gratitude of the delegation for the honour which had been conferred upon Mr. Swasey. He had been much impressed by observing in that morning's paper a communication referring to science libraries and the need for co-operation, on which subject he had intended saying a few words on the previous day. The article indicated the need for classifying scientific literature. In America that had been accomplished by bringing together the libraries of four of the engineering societies in one place. The ownership of the libraries remained with each of the societies, but the libraries were catalogued as one. A valuable feature of the scheme was the facility it afforded to members of the societies, to obtain from the director the bibliography of, and references to, the subjects in which they happened to be interested at the moment, and the use of the library in that manner was rapidly extending. The united engineering societies held the legal title to the property, which, in value, now amounted to two or three million dollars. Referring to the Federated American Engineering Societies, the American Society of Civil Engineers, having a valuable building of their own, found it difficult, at first, to join the other societies, but a few years later the Federated Societies enlarged their building, and the Civil Engineers were now housed with them. The speaker quite realised that there might be difficulties in bringing about in a short time in this country a similarly intimate relationship between instutitions as far as housing was concerned, but he thought great advantage would be derived from associating the libraries in the way he had indicated. As he had said at the Civil Engineers' Conference on the previous day, he would be glad to assist the councils of the Institutions with details of the arrangements in the States.

The general meeting then concluded, the usual formal business having been first transacted.

INTERNAL-COMBUSTION ENGINE THEORY.

At the meeting of the Conference held in the Library of the Institution, on Thursday, June 30, at 10.45 a.m., the chair was occupied by Mr. Richard W. Allen, C.B.E., Member of Council. The first paper set down for reading and discussion was one entitled "Internal-Combustion Engine Theory, with Relation to Higher Economy," by Mr. H. E. Wimperis.

The chairman remarked that the council had considered at great length what should be the motto for the present discussion. Anyone who had been present at the meeting of the Institution of Civil Engineers on the previous Tuesday would doubtless have been alarmed on learning the enormous rate at which the world's stores of coal and oil were now being consumed, and would agree that there was no time in the history of any nation when it was more essential to economise these important fuels. The motto chosen for the Conference had therefore been "Means of Improving the Thermal Efficiency of Heat Power Plants," and if, as a result, it were possible to attain higher efficiencies in the operation of our power plants, the supplies of coal and oil in the world would be conserved. The council had, accordingly, invited Mr. Wimperis to contribute the first paper which was on "Internal-Combustion Engine Theory."

Mr. H. E. Wimperis, in his notes, explained the state of high thermal and mechanical efficiency, to which internal-combustion engines had now attained. Various means for accomplishing a substantial increase in overall efficiency, which have been put forward from time to time were discussed, and it was pointed out that a change in the working medium offered little prospect of gain. Any change of cycle usually involved considerable mechanical modification and corresponding loss of simplicity. Reference was also made to the recently-published results of Mr. Ricardo's experiments on stratification and supercharging as offering grounds for hopes of future improvements (see ENGINEERING, vol. cxi, pages 28 and 652).

The discussion on this paper was opened by Mr. James Richardson, B.Sc., who said that after having heard some of the papers read on the previous day at the Conference of the Institution of Civil Engineers, together with the remarks of Mr. Wimperis, one could not but be impressed by our indebtedness to engineering developments resulting from war efforts, and by the full way in which our dependence on efficient utilisation of available fuel supplies was now recognised. As a result of the intense work done on aeroplane engine research during the war, considerable developments could be forecasted in connection with the prevention of detonation and pre-ignition and the attainment, by this means, of higher efficiencies for the internal-combustion engine. The experiments under discussion had been concerned, the speaker understood, with small-sized prime movers, and the deductions to be drawn from them were not necessarily directly applicable to engines of larger cylinder capacity. In connection with the utilisation of the toe of the diagram, which, of course, was a distinct theoretical gain, he thought it would be found in practice costly to expand the gases down to a low pressure. Mr. Wimperis had observed that the question of the internal-combustion turbine was one more for the metallurgist than anyone else, yet where higher power internal-combustion engines were concerned improvements also turned largely upon metallurgical research, since with larger engines, when increased efficiency was sought, there still remained the question of the limit of heat transfer from the working fluid through the containing walls of the materials available to-day.

Dr. Bacon recalled the experiments of the late Professor Hopkinson on water injection in gas engines some years ago. The results gave rise to certain hopes towards higher efficiency and simplicity of construction, but little had recently been published on this subject.

Professor Low referred to the constant pressure cycle, upon which the Diesel engine worked, but where combustion took place in the engine cylinder. It had been suggested that advantage would accrue if combustion could take place outside the cylinder; if the fuel and air required for combustion of fuel could be pumped into a high-pressure reservoir and a continuous combustion of the fuel could take place. If the heated products of excess air were then fed into the engine, it could work more or less like a steam engine. The obvious objection was that the high temperature gases would have to pass through an inlet valve, which raised serious difficulties, but it was just possible that, with improved materials, special design of valve and facilities for cooling these might be overcome. He had attempted to make such an engine over twenty years ago but had not proceeded far before realising the difficulties referred to. On the afternoon of the previous Tuesday he had visited the National Physical Laboratory, and had been interested in the apparatus now in use there for making experiments on the detonation of gaseous mixtures. He had learnt there that the question of the temperature of the gas and the pressure at which it was exploded had very little influence, and he gathered therefore that there was no particular difficulty in burning gas at a high pressure or high temperature, and that the continuous combustion of the fuel in a sort of Bunsen burner was a possibility. He had been told that experiments on the continuous combustion of fuel in that way, had been made, and that continuous combustion for a certain time, had been achieved, but troubles were encountered by the sudden extinction of the burner, due probably to fluctuation of pressure on the fuel or the air.

Mr. Stern said he did not consider that there were great hopes of improving the efficiency of the internal-combustion engine. The aero engine of to-day was almost perfect thermally. Research was more needed on the mechanical side. The speaker had recently seen one or two applications

of the internal-combustion turbine, and generally speaking, he believed that the theoretical conclusions arrived at had been borne out. The practical difficulties were such that the engine would never be able to compete with other prime movers. There was an interesting feature in the Holtzwarth turbine, namely, the very efficient regenerator attached to the exhaust. This regenerator served to drive a steam compressor which gave all the compressed air required. In big power plants exhaust regenerators on such a principle would lead to important saving. In the earliest type of constant-pressure turbine working on this principle, the fuel and air were introduced into a combustion chamber, burnt there and expanded through a nozzle. After expansion and cooling, the energy was extracted in a wheel. With combustion of this type extraction of the energy by a wheel was necessary, because if the attempt were made to extract the energy from the mixture in a cylinder there would be every chance of considerable loss on the way. As an instance of the important influence of the design of mechanical details in the efficient performance, it was recalled that a certain German engine, although having the low compression ratio of 6·5 to 1 had a very high efficiency, and that the fuel consumption was of the order of 180 grammes per brake horse-power per hour, which was considerably less than could be obtained here with the same type of engine and the same compression ratio. The difference was accounted for by the fact that with the German engine, each cylinder did its proper share of the work.

Mr. E. W. Petter referred to the difficulty of getting the right balance between the heat necessary to produce energy and the necessity for getting rid of the waste heat after all the work had been got out. This was accentuated in dealing with large sizes of engine having large masses of metal, which collected heat, and were thus liable to give trouble. With regard to the question of water injection for cooling the gases and preventing detonation and pre-ignition, he felt that the hopes which earlier had been entertained on this score had been dashed to the ground. The plan had been under suspicion before the war, and the war gave the *coup de grace*. During the war engineers had been called upon to work internal-combustion engines with fuels not previously used. Fuels containing a high percentage of sulphur, if water were injected, into the cylinder would cause very bad effects. He recalled that at a meeting of the Institution this question had been raised, and one speaker had remarked that the life of an oil engine using water injection was anything from 10 hours to 10 weeks.

Colonel Davidson remarked that it was impracticable to use the full efficiency of the ordinary cycle in most engines as applied to mechanical transport, because the design was not entirely suitable. Nearly all such engines were grossly over-lubricated, with the result that the possible compression could not be used, allowance having to be made for pre-ignition due to over-lubrication. In his experience builders had emphasised that the lubrication should be ample; whereas his experience was that the lubrication was too great, and, in view of the trouble mentioned, had thought that it should be cut down, Another difficulty was of a metallurgical nature. It was not possible in many cases to use the best shape combustion space because of the failure of materials for valves. In this connection he referred to commercial vehicles and not to high-class aircraft engines. Doubtless the difficulty was associated partly with expense, and greater efficiency could be obtained if more suitable materials were available at lower prices.

Mr. Acland commented on the fact that, after twenty years of progress improvement in efficiency—in the commercial, not the scientific sense—was disappointing. The steam engineer was apt to quote efficiencies for steam, but it was coal, not steam, that had to be paid for. It was, therefore, appropriate to consider the question of efficiency in reference to fuel consumption. With the gas engine, for instance, the efficiency of the producer should be taken into account, as well as that of the engine. The "Still" engine with which he was associated had started from such a basis, *i.e.*, analysis (if possible) of the losses. It was of little profit to take an inefficient engine, and therefore Mr. Still began his experiments with the Diesel type, in which the main losses were a minimum and occurred in the jackets and the exhaust. Much ingenuity had been spent on reducing these to their probable minimum by transforming them into useful steam. The utilisation of exhaust gas in this connection had been frequently tried in the past, but the steam had generally been used for some other purpose, such as process work, and not for increasing the power of the engine. Mr. Still had conceived the idea that the steam so raised might be used in the same engine, and that the heat recovered from the jacket losses should also be used, by putting the cylinder jacket into a boiler circuit, the jacket being completely filled with water at the same temperature and pressure as in the boiler, so that the heat passed through the walls of the cylinder into the jacket assisted in raising useful steam. In this way a 24 per cent. total heat loss in the engine was reduced to less than 10 per cent. This reduction of loss was not, however, all profit, on account of the increase in exhaust gas temperature. It was possible, however, by the means indicated, to recover 60 per cent. of the heat losses and get back, as useful work, 15 per cent. Any gain in efficiency on the combustion side was a direct gain, but any increase in steam production was limited by the efficiency of the steam engine, so that the less steam made, the more efficient the whole plant. The combustion side of the engine was the more important, and the reduction in jacket losses was probably the most effective way of improving the overall efficiency.

Mr. H. E. Wimperis then replied to the discussion. Mr. Petter, he remarked, had referred to the cooling of exhaust gases and to water injection, and on the latter point Mr. Wimperis would say that had Professor Hopkinson not lost his life in the war more might have been heard of the subject of water injection. With regard to cooled exhaust gases, if these were admitted to the inlet stroke the liability to detonation was reduced. The question had been regarded previously as an unsolved problem, but attention might be drawn to Colonel Tizzard's communication made to the North-East Coast Institution of Engineers and Shipbuilders,* in which he suggested that detonation was more a function of temperature than of pressure. Taking the analogy of a match burning in the wind, if the wind blew the heat away more rapidly than combustion could supply heat, the match would go out. Supposing, however, the temperature were raised in some accidental way, then if the rate of combustion increased, due to increase of temperature, faster than heat was dissipated to the wind, the match would explode. Detonation was more a temperature function than anything else, depending not on compression temperature, but on final temperature.

Mr. Wimperis fully concurred in Mr. Richardson's conclusions regarding the metallurgical work still required to take the fullest advantage of existing cycles, and gave instances of the improvements mechanically and theoretically that had been achieved by the substitution of aluminium for cast-iron pistons, where in one case the temperature of the piston had been reduced from 400 deg. to 150 deg. C.

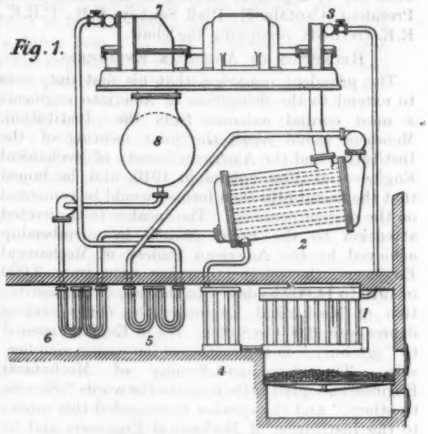
High Steam Pressure and Economy of Steam Engines.

The next paper taken at the meeting in the library, on Thursday, the 30th ult., was one entitled "High Steam Pressure and other means of Increasing Economy of Steam Engines," by Mr. Frederick Samuelson. In the absence of the author, this paper was read in abstract by Mr. Halliwell.

In this paper the author pointed out that present methods of generating power through the medium of steam were far from efficient, and advocated an increase of the temperature range. An interesting method of increasing this range had been tried experimentally in America by Mr. Emmott, who operated a mercury turbine in series with a steam plant. The boiler for the steam plant acted as condenser for the mercury plant, and a gain of 40 per cent. to 60 per cent. in thermodynamic efficiency was realised. The arrangement is shown diagrammatically in Fig. 1. The readiest method of improving power station efficiency was, however, to increase both the pressure and temperature of the steam. The efficiency increased considerably with increasing pressure and temperatures, as was indicated by the curves reproduced in Fig. 2. The author considered that 800 deg. F. was a safe working temperature, and with this limit the efficiency would increase with increasing pressures. The gain was augmented by increasing the temperature of the feed. Thus with 350 lb. pressure and a superheat of 300 deg. F., and a 29-in. vacuum, an efficiency of 26·38 per cent. could be obtained, but by raising the feed temperature to 300 deg. F. an efficiency of 28·44 per cent. could be realised. The steam for heating the feed was drawn from intermediate stages of the turbine. In some cases, owing to bad

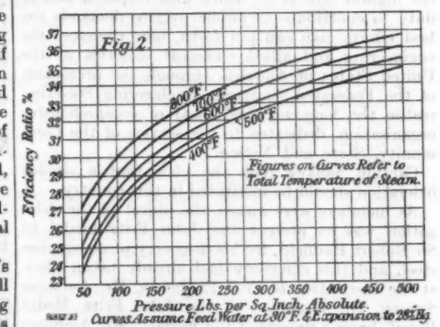
MERCURY VAPOUR IN THE GENERATION OF POWER.

Fig. 1.



1. Mercury Boiler
2. Condenser Boiler
3. Mercury Turbine
4. Mercury Preheater.
5. Steam Superheater
6. Feedwater Heater
7. Steam Turbine.
8. Steam Condenser.

Fig. 2.



feed water, evaporators must be supplied, and these could be operated by the condensate from the feed heater. With this system of feed heating the flue gases would leave at a high temperature, but might be employed to pre-heat the air for the furnaces. A 1,500-kw. plant constructed by the author's firm and operated with steam supplied at 350 lb. pressure and at a temperature of 700 deg. F. had shown a coal economy of 15 per cent. to 20 per cent. They had no trouble from failure of the materials used in the turbine, which were steel and phosphor bronze.

The Chairman, in opening the discussion, regretted that considerations of cost had prevented the printing of some of the papers in time for the meeting, but all would appear in the bound volume of the proceedings.

Mr. Fedden referred to experiments with a mercury-steam turbine made some fifteen years ago in Berlin. Such a turbine would have to be extremely well made, or there would be danger to bystanders from leakage. With regard to the diagram (Fig. 2), it appeared that at 200 lb. pressure and 700° F. the efficiency ratio was about 32 per cent., whereas at 350 lb. pressure and 700° F. the ratio became about 34½ per cent., the gain being only 2½ per cent. He would ask the

* See ENGINEERING, vol. cxi, page 652.

author what was the extra capital expenditure on boilers and fittings and steam-pipes, and whether he had any figures for maintenance. It was true that better thermal efficiencies might be attained, but the question really turned on the efficiency of the whole plant, from the coal to the switchboard. He would like practical proof of gain before abandoning the cast iron economiser and getting down the temperature of the waste gases from the boiler. He had used air heaters for twenty years, more or less, and found that owing to corrosion the expense of maintenance was considerable and the pipes also plugged up. In some cases, moreover, he had a surplus of hot air which had to be by-passed. He thought, therefore, that unless different arrangements were made to utilise the hot air, there would be another source of loss with the high-temperature turbine.

Mr. Selby said that it had long been known that thermal efficiencies might be raised by using more than one working fluid, but in practical work the main question was not merely the thermal efficiency but the total net gain. With regard to higher pressures, there was hesitation in going much above 300 lb. to 350 lb. The case of the Belleville boiler would be recalled, and the substitution of the Babcock type. High pressures were chiefly used in the Royal Navy. With the very high pressures now contemplated, mechanical considerations became important, as large and heavy plates called for a certain amount of care. There was, however, no real difficulty in the matter, and, so far as he knew, no limitation. The speaker cited a case in which the pressure used was 475 lb., with very promising results. There had been no official pronouncement, but the engineers of the station concerned would in due course publish particulars. With regard to high temperatures a very important firm of steam-pipe makers had investigated the question. They were not at present prepared to deal with temperatures higher than 700 deg. F., but on the Continent there were instances in which temperature approaching 750 deg. F. were employed.

Mr. Oxlin considered that with the materials at present in use, it did not seem possible to improve the economy of the internal-combustion engine by more than 1 per cent., or 2 per cent., or 3 per cent. He felt that it would be very interesting if Mr. Halliwell could give more information about the turbine to which he had referred, in which, it seemed to the speaker, the question of materials was of first importance. With regard to high temperatures and pressures, it was the general opinion on the Continent that a turbine working at 350 lb. and 750 deg. F. required very careful handling.

Mr. Rolf regarded as a serious limitation to the present design of the internal-combustion engine the fact that engineers were compelled to work with materials which were really incapable of withstanding the severe conditions of operation. A wide field for investigation was accordingly open to the newly-inaugurated Cast-Iron Research Association. Such research associations would be capable of far more complete and extensive experiments than were possible to the individual manufacturer.

Mr. Jockle expressed disappointment with the somewhat brief particulars given in Mr. Samuelson's paper. He thought that at present the limits of pressure had practically been reached, and also the limits of temperature, in this country, on the Continent and in America. There were one or two interesting plants which it was hoped would afford data within the next twelve months or so. He instanced the Glasgow Corporation Power House, where, in the boiler-house, the working pressure used was 275 lb. to 250 lb. at the turbine stop valve—and the temperature was 700 deg. F. This station was opened last September. He understood that satisfactory results were being obtained. He cited further works at Etchells, Birmingham, and at Manchester. But for the next two or three years he certainly thought the limits both of pressure and temperature had been attained. That being so, search must be made for other means of improving the economy of steam engines, particularly turbines. He had tested many types of turbo-alternators, condensers and boilers, and he was convinced that something could be done with respect to condensers as applied to steam turbines while something might also be done for the low-temperature engine. In the exhaust branch of the turbine, simple calculation showed a temperature difference of 5 deg. between the exhaust steam and the condensate, and in the case of a modern 6,000-kw. or 7,000-kw. turbine this involved a waste of something like 500,000 B.Th.U. per hour. Assuming a boiler-house efficiency of 70 per cent., easily obtainable in practice, a modern power-house would show a heat consumption of approximately 27,000 B.Th.U. for every kilowatt-hour of energy generated. As he had indicated, there were enormous losses taking place in the condenser plants of power-stations. While holding no brief for any particular condenser—he had tested and applied many makes—he knew of only one which gave reasonable thermal efficiency, namely, the "Contraflo" condenser. Wonderful results might be achieved with this in combination with the radial flow reaction turbine.

The Chairman remarked that Mr. Selby had pointed to the practice of utilising pressures above 300 lb. in the boiler, and had, in that connection, referred to the practice in the Navy. The Navy, however, had always adopted a policy of exceptional caution. There was no difficulty in obtaining a boiler for 300 lb. pressure and 200 deg. of superheat, but it was quite another thing to specify a boiler for 300 lb. of steam and require 700 deg. total temperature. There could be no progress without experiment. At the outbreak of war aeroplane engines were not made in this country, but were purchased from the Government of France. The high quality steels required in the construction of aeroplanes were obtained from Liége. When Liége fell, the production of aeroplanes fell also. That was the position in 1914. In a short space of time the professors of Sheffield succeeded in producing the steels necessary for aviation engines. Previously the steels were produced with a maximum tensile strain of only 36 tons, but in a few months steels equal to a tensile strain of 100 tons were made. If, therefore, the very high pressures and temperatures referred to were necessary, he would suggest referring the matter to the professors of Sheffield, and he was confident that they would be able to provide a material which would stand up to the required conditions.

Mr. Halliwell, replying for the author, observed that the paper was limited to 1,000 words, and it was difficult, within such limits, to give details of particular improvements. The intention of the paper had been merely to stimulate discussion and indicate desirable directions for research. He would point out that the mercury turbine worked up to a load of 1,000 kw., which must be regarded as a rather substantial load. Mr. Fedden had alluded to high pressures, but had made no mention of the trouble arising from air in the water, which was most marked in the case of high-temperature and high-pressure plants. It was practically easy to obtain pure water, free from solids, but, apparently, it was a very difficult matter to get water free from gas. If water was hard, the carbonic acid gas, eliminated from hard chalk on evaporation, found its way into the feed water and set up corrosion in the boiler and economiser. On the question of expense of upkeep of air heaters, raised by Mr. Fedden, he (Mr. Halliwell) would refer members to the paper on "Air Heating," by Mr. Patchell, to be read the next day. In reply to Mr. Oxlin, the speaker would not say much about turbine plant, but would direct Mr. Oxlin's attention to an interesting article, by Mr. Kilburn Scott, published a week or two earlier in *The Electrician*. Mr. Rolf had suggested that cast-iron could be made to stand high temperatures. The speaker's experience with turbine work had led him to the conclusion that cast-iron was unsuitable for temperatures higher than 500 deg. F. For high temperatures—of 750 deg. to 800 deg.—steel was employed throughout for turbine construction, with the exception of the phosphor bronze blades. Mild steel would stand up quite well to a temperature of 800 deg. F. The troubles the speaker had experience of were not so much connected with the material used but were due rather to the novelty of the conditions for which the plant had been designed. The speaker looked forward with great interest to the results of the plant at Dalmarnock and the other instances mentioned by Mr. Jockle.

The Chairman then brought the meeting to a close with the announcement that Mr. Pendred had kindly undertaken to act as editor of the "Proceedings" of the Conference. Mr. Pendred had, however, expressed a desire for two assistants in each section, and accordingly the Chairman would ask Captain Bacon and Captain Teed to act in that capacity so far as the present meeting was concerned.

Chemistry of Combustion. Blast-Furnace Gas.

Papers on the chemistry of combustion and on blast-furnace gas were discussed on Thursday morning in the Reading Room, Dr. H. S. Hele-Shaw, F.R.S., Vice-President, being in the chair. In opening the proceedings the chairman extended a special welcome to Lady Parsons, President of the Women's Engineering Society, and to the lady members present with her at the meeting. He then called upon Mr. E. V. Evans, F.I.C., of the South Metropolitan Gas Company, to read his paper on the "Chemistry of Combustion."

The Chemistry of Combustion.

In introducing his subject, Mr. Evans stated that he wished to appeal against the use of raw coal for heat generation for two specific reasons: (1) The reactions, both physical and chemical, taking place during the combustion of raw coal were highly complex, and it was very difficult consequently to control the combustion and to obtain the maximum conversion of energy; (2) The raw materials required for the promotion of our chemical industries were lost. The combustion of carbon was commonly represented as a simple bimolecular reaction (1) $C + O_2 \leftrightarrows CO_2$, reversible only at very high temperatures. The carbon dioxide, further, reacted with incandescent carbon; (2) $CO_2 + C \leftrightarrows 2\,CO$, again a reversible reaction. These two producer-gas reactions had been believed to represent the mechanism of the production of CO when a limited volume of air was passed through a bed of incandescent carbon. A large amount of research had been carried out to determine the equilibria of these reactions. But the combustion even of carbon was of a more complicated nature, the primary oxidation product of carbon being a complex compound of transitory existence which decomposed into a mixture of CO and CO_2 in proportions changing with the temperature. The fundamental point of this hypothesis was that some CO was directly formed (third reaction). In the gas generator this CO was produced in the lowest layer of the fuel bed where it was surrounded by oxygen molecules (which had not yet reached the surface) and was therefore liable to be oxidised to CO_2 before travelling far. If the bed were more than a few inches in thickness and at sufficiently high temperature, this CO_2 would partly be reduced to CO again (reaction 2); the CO would then be found as a constituent of the producer gas or would burn with its characteristic blue flame, according to the conditions of the air supply.

The combustion of hydrogen was a trimolecular reaction $2H_2 + O_2 \leftrightarrows 2H_2O$, reversible at very high temperatures, and did not call for further remarks. The combustion of the simpler gaseous hydrocarbons was more complex. Combination with oxygen did not really take place in a simple manner at high temperatures. At low temperatures, in the presence of a catalyst—hardly ever absent, we might add—many intermediate products were formed before the ultimate products CO_2 and water vapour emerged. Thus the slow combustion of ethane at 400 deg. C. yielded ethyl alcohol, glycol, acetaldehyde, formaldehyde and formic acid, oxygen entering at several stages. The apparent simplicity of the reaction in the combustion of simple gaseous hydrocarbons was really due to the high velocity of reaction which masked the complexity of the processes. As the hydrocarbon molecules themselves became more complex, the complexity of the reactions, insufficiently studied so far, also increased, and a culminating point was reached when the formation of intermediate products could no longer be masked; the result was incomplete combustion.

In the case of raw coal now a number of side

reactions, both physical and chemical in nature, further complicated matters. Long before the ignition temperature of coal was reached—which for this discussion might be regarded as the temperature at which active oxidation occurred—some of the coal substance melted and was decomposed, gas was liberated, and the decomposition products might also melt and decompose further. When the boiling-point of any of these liquids was lower than the temperature of decomposition, distillation would immediately take place, and when the vapour came into contact with a cooler zone, condensation and smoking would result. The gas evolved might be ignited; but it was impossible to predict the sequence of events and to control the conditions to which the combustion products would be subjected. The coal substance undoubtedly underwent extensive decomposition in the solid or liquid form, before distillation. Whether the distillation products would ignite or escape as smoke, depended upon the relation between ignition temperature and boiling point; where there was a large temperature difference there was obviously greater opportunity for the gas to be carried away into a cooler zone before combustion occurred. Another factor to be considered in connection with smoke combustion was that smoke was usually evolved in a zone already highly-charged with combustion products from the fire below. A suitable excess of air should be provided, and if that air were admitted above the fire level, it should be preheated not to cool the products below the ignition temperature.

The use of raw coal was also deprecated because of the impossibility of controlling the combustion, and that led either to the production of smoke or to the use of a large excess of air. This did not apply to oil fuel and powdered coal, the combustion of which might be controlled in the same way as that of gaseous fuel, though perhaps not to the same extent. Finally the combustion of raw coal meant to the chemist an appalling waste of inorganic and particularly organic chemical products upon which we mainly depended in building up an organic chemical industry successfully to compete against that of Germany.

In inviting discussion of this paper, Dr. Hele-Shaw remarked that the general principle of coal combustion had never been put in so simple language; he referred also to the by-products question, of which he had heard nothing in his school days. Mr. P. V. Vernon, the first speaker, put a question regarding the use of powdered coal in rotary kilns. No smoke was observed in a 140-ft. kiln; was that because there was no incomplete combustion? Sometimes the coal was powdered and dried at the same time, and the water vapour passed into the furnace; the flame then seemed to be longer. He supposed that the reactions, though simpler than in a coal bed of ordinary fuel, were repeated, and that there was burning, dissociation, and again burning. Mr. R. H. Cabena also had a question. He spoke of a vertical boiler, the furnace of which, though not in perfect condition, gave a clear gas, but began to smoke immediately when the superheater was added.

Sir Gerard Muntz, Bart., rising next, said that as a metallurgist he wished to congratulate the author upon his exposition, from the study of which some experts in furnace construction might profit. Such experts had promised him marvels, but they seemed to have lost sight of the intermediate stages of combustion; he could not help remembering Sir Frederick Bramwell's definition of experts. When oil fuel had become available they had first tried air pressure with good results; then steam had been used with better results still, but after 24 hours their furnaces had stopped, because the bricks down below had melted. Mr. Evans had given them the reasons. Mr. Max Lawrence submitted similar considerations. Pointing to a diagram of a water-tube boiler (which was hanging on the wall of the room) in which the coal flames directly impinged upon the water tube, he said that the diagram showed how not to do it. The difficulty had been to get firebricks which would not melt and even for carbonising furnaces compromise was necessary in order to spare the furnace.

Major Wraith said that two facts, pointed out by Mr. Evans, should be recognised. Bituminous coal was a mixture of solid, liquid and gaseous constituents and should never be used as a fuel; we should first break it up into its constituents to burn it efficiently. Pulverised coal had been used with fair efficiency; that fuel was not a raw fuel, however, as it had undergone a certain amount of preparation.

Mr. H. M. Ridge agreed with the other speakers as to the value of the paper. The difficulty of obtaining complete combustion with raw coal was accentuated where the flames impinged upon comparatively cool tubes, causing condensation and sooting. He had overcome this difficulty by carrying out the operation in two or three stages in the same apparatus: the raw coal was heated to drive off the volatiles and to make coke; the coke was burned to CO_2 by restricted admission of air, while the gas from the volatiles passed over the incandescent coke; by the admission of preheated air, complete combustion of the gas was then obtained. By building the fire brick apparatus in front of the boiler complete combustion was easily and permanently maintained with a minimum of labour and supervision; in work's practice he he had no difficulty in working with waste gases, carrying 17 per cent. of CO_2.

Mr. Pendred asked under what conditions oil should be burnt under boilers. People said, that we must allow a certain amount of smoke; was that so? Power stations certainly sent up considerable amounts of smoke of a thick type when burning oil.

Mr. Marshall, of the Scarab Oil Burner Company replied to this question "as one of the people responsible for the smoke." You ought to have a pale grey smoke, he said; if not, too much air was admitted. On board ship each boiler of a battery could be controlled separately; that was not possible in power stations with common main flues, and as many of the oil plants had had to be put down in a hurry, they had not had time for exhaustive experiments. On the request of the chairman, Mr. Marshall drew a sketch of their oil-burner arrangement for a Babcock boiler. The burners were mounted in the front of the combustion chamber; there was a false bottom of firebricks in the chamber, with air passages underneath, one on each side of a burner; the air passed in at the front, curved back to the burner in a U, and was then allowed to escape upward into the space beneath the tubes.

In calling upon Mr. Evans to reply to the speakers, Dr. Hele-Shaw said that he remembered a firm claiming to burn more air than any other!

In his reply, Mr. Evans stated, that control of the air supply was, of course, one of the main points. We might accelerate and simplify the reactions by admitting too much air. When we added steam we passed to a water-gas reaction. Mr. Cabena had smoke trouble because the insertion of his superheater reduced the temperature. Mr. Evans quite agreed with Mr. Ridge, whose ideas as to double-phase combustion were absolutely sound. He also agreed with Mr. Marshall's remarks on the complete combustion of oil; we might learn to realise that; for the present we might have to put up with the pale grey smoke when burning complex bodies.

Blast-Furnace Gases.

The second paper, by Mr. Alfred Hutchinson and Mr. F. Bainbridge, on "Blast-Furnace Gases," was read by Mr. Cyril Pease, Mr. Hutchinson speaking subsequently. The paper reviewed the utilisation of furnace gas energy on historical lines. The old furnaces were open at the top. In 1828 James Neilson advocated a change in the furnace by the use of a hot blast, while Faber der Faur was credited with first utilising the gas. Bunsen and Playfair, conducting their epoch-making experiments at Alfreton in 1875, concluded that 81·54 per cent. of the fuel energy was lost in combustible matter still fit for use, and that only 18·46 per cent. was really utilised in the furnace processes. The gases first served merely for heating the brick-lined blast stoves, later they were burned under boilers and even this dirty gas soon reduced the cost of steel production by as much as 10 per cent. In the last quarter of the past century, 40 per cent. of the blast-furnace gas served for heating the blast, and 50 per cent. for steam raising, while 10 per cent. were lost at the bell. Thwaite's demonstration in 1894, that blast furnace gas could be burned in gas engines, and the advent of the large gas engine revolutionised the blast-furnace gas industry.

The main objections to this gas fuel were soon met; the thorough cleansing and cooling of the gas proved difficult, however. English iron smelters merely passed the dusty gas through underground mains and had to shut down periodically for cleaning and repairs. Faber der Faur, at Wasseralfingen (Württemberg), sprayed the gas with water, but had trouble with the mud; Zschock and Reisen then introduced the gas washers which had made the introduction of large gas-engine plants possible at the Skinningrove Iron Company and elsewhere. The wet method was in England followed by dry cleaners, such as the Halberg-Beth and the electrostatic deposition systems, the former method gave a clean gas for the engine, the latter was sufficient for using the gas in stoves and boilers, and was followed by the final discovery of the Reisen cleaning process. These latter methods had individually some advantages over the others when existing plant, ground space and gas mains were taken into consideration, and seemed to give general satisfaction wherever installed. As regards the mattress dry cleaning systems, satisfactory results were reported from America, but no plant had so far been completed in England. The manifold advantages of cleaning blast-furnace gas had clearly been demonstrated in the works of the North Lincolnshire Iron Company. In the Cleveland district the average coke consumption at the blast furnace per ton of pig iron was 23·5 cwt., and when steam engines were used, the distribution of the gas produce was: 50 per cent. to boilers, 30 per cent. to stoves, 20 per cent. surplus, there being a total of 184,000 cub. ft. per ton of pig iron produced. In plants smelting Lincolnshire ores 33 cwt. of coke were consumed, in hematite plants, 21·33 cwt., with a corresponding increase or decrease of spare gas.

The average analysis of the gas from a furnace smelting Cleveland ironstone was in the dry state in per cent.: CO_2 10, CO 30, hydrogen 1, nitrogen 59, the net calorific value being 100 B.Th.U. per cub. ft. at 15 deg. C. and 760 mm. American blast furnace gas gave the following average composition in per cent.: CO 23, CO_2 12, methane 2, hydrogen 2, water vapour 3, nitrogen 58. The cardinal feature of new development was to concentrate by-product coke ovens, blast furnace and steel works in one plant. With the utmost utilisation of gases from blast-furnace and coke ovens it should, according to Dr. Bone, be possible to produce the ton of finished steel section from Cleveland ironstone at 1·6 tons of coal. Assuming a minimum surplus of 50 per cent. of blast-furnace gas available for the steel works and the mill, this gas, together with the coke oven gas, should make available as a maximum per ton of pig iron 92,000 cub. ft. of gas of 9,000,000 B.Th.U., plus 8,000 cub. ft. of 2,400,000 B.Th.U., together 100,000 cub. ft. of 12,600,000 B.Th.U., equivalent to the heat in 8 cwt. of bituminous coal. As, however, the efficiency of the boilers and gas producers of steel works would hardly exceed 75 per cent., and as steam engines were less efficient than gas engines, the coal equivalent of the surplus gas should be raised to 10·6 cwt., and possibly more. Thus blast-furnace gas should play as great a part in the economic history of the metal industry and allied trades as any other type of fuel.

Mr. R. P. Kerr, rising first in the discussion, expressed his appreciation of the paper, and his regret that so little regard seemed to be paid to the publications of the Cleveland Institute. How much blast-furnace gas was actually being utilised, he asked. The utilisation of water power had duly been considered during the war; this gas power was much more certain and was, moreover, available in parts where it was most wanted, and yet it was hardly possible to get definite information. Most of the gas was allowed to pollute the atmosphere.

Mr. A. Hutchinson, responding to a call by the Chairman, said that Mr. Bainbridge, their chief chemist, was more responsible for the paper than he was himself. Those who had visited Germany and America knew what had been achieved in fuel economy there. Mr. Evans had (in the preceding paper) referred to the importance of the

by-products. During the war they had over here in steel works carried the recovery actually down to the T.N.T. stage; they might compete with Germany in dyes, napthalene, etc., but the question was, whether it was advisable to carry the process to the end or to sell the intermediate products. The gas had been stripped of benzene. They were at Skinningrove recovering the ethylene as well, and transforming it into alcohol. [Professor Hele-Shaw here interposed the question whether these recovery processes were going on or were we dropping back? Further, might the improvements not possibly destroy other more valuable products?] Mr. Hutchinson replied that the stripping of ethylene and of benzene did not impoverish the gas to any serious extent; the gas remained good enough for most purposes. We were not going back, he thought; whether we should go so far as Germany was doubtful.

Major H. M. Bellamy inquired about super-power stations. It ought to be possible to utilise gas in industrial areas to the extent it was used near Essen. The Committee on Transport had he believed turned down the idea of gas for super-power stations.

Mr. A. C. Pain, quoting various recent papers on the subject, remarked that when power was offered to corporations in the form of electric current, vested interests were roused, and this remark led to others by the Chairman and Mr. Hutchinson also on the difficulties of the storage of electricity and of blast furnace gas. Mr. Hutchinson pointed out that corporations did not want the extra power over week-ends when metallurgical works could best spare it. Mr. G. S. Taylor, of the Home Office, referred to the danger of distributing so highly poisonous a gas by mains. Mr. J. L. Hodson, of Messrs. George Kent and Co., raised the question of gas meters; they had had serious troubles with metering blast-furnace gas in South Africa, because the dust put the meters out of order, those troubles had been overcome, but if the dust were removed before the gas entered the mains, matters were altogether simplified.

At this point the meeting adjourned until Friday.

BOILER HOUSE MANAGEMENT.

Under the chairmanship of Mr. W. H. Patchell, the members more particularly interested in boiler operation assembled in the Council Room at 10.45 on Thursday, June 30, to hear a short paper on "Boiler House Management (General Causes of Boiler Inefficiency)," by Mr. David Wilson, who, as the chairman remarked in introducing the author, had acted as the right hand man of the Coal Controller during the war.

Mr. Wilson said that, in the interests of brevity, he had had to assume that the causes of wastefulness in boiler rooms were generally known. Much had been written on this subject, and he himself had delivered many lectures on it, but the suggestions made for improving matters were quickly forgotten. A modern plant would show on test an efficiency of 85 per cent., and it could be operated in ordinary working at an efficiency of 75 per cent. to 80 per cent. In spite of this the average efficiency obtained in practice was less than 50 per cent. The low working efficiency of the plants belonging to ordinary industrial concerns was rarely realised, because no proper records of coal and water consumption were kept. Many such plants were also out of date. The chief cause of the deplorable inefficiency was lack of proper supervision. A scientifically-trained engineer in charge would soon improve matters and convince the management that it would pay to provide facilities for proper operation. The ordinary manager was doubtful of promises to save him 10 per cent. or 20 per cent. of his fuel bill, and he would not pay an adequate salary for a man who could do this. An annual sum equal only to 1 per cent. of the coal bill of a large concern would pay the salaries of several of the best men available, and the savings which would be made by employing such men would vastly outweigh the cost. Proper boiler-house management was not a matter of a few random tests, but involved a continuous supervision of the methods and results of operation. Until the status of the boiler-house staff was raised and their importance realised, a high operating efficiency would never be obtained. The coal consumption of some plants was awful, and until the actual figures were obtained and compared with the possible figures, managers would not realise how bad things were. The speaker was not a supporter of Government control as a general thing, but he thought some kind of supervision over the consumption of coal was desirable, and he would suggest that it should be brought under the jurisdiction of the Board of Trade. The Federation of British Industries were doing good work in assisting firms to improve the operation of their plants, but they had not the authority really required.

Mr. S. E. Fedden said that Mr. Wilson had rightly pointed out that the boiler-house was the root either of economy or waste in steam plants. The annual power consumption of the City of Sheffield had jumped from 20,000,000 kw.-h. before the war to 172,000,000 kw.-h. Much extra plant had to be put down to cope with the load, and the coal consumption rose to 5,000 tons per week. The speaker had put shift engineers in charge of the boiler room, but it was soon evident that their other duties prevented them giving the necessary attention to combustion. So he engaged a good chemist to look especially after this, and he soon had two or three assistants to help him. The general efficiency of the boilers had in consequence been raised from 65 per cent. to between 72 per cent. and 75 per cent. To make a saving of 10 per cent. on 5,000 tons of coal a week, one could afford to pay adequate salaries to men who brought it about. During the war Mr. Fedden had employed 160 women stokers in the boiler-house, with 1 man to every 10, to do the heaviest of the work. He had instituted lectures on combustion for the women after working hours, the women being paid to attend them. They had benefitted greatly by the lectures, and had proved most intelligent and capable firewomen. After the war, the speaker had provided similar facilities for the firemen, but they would not take advantage of them, the presence of public-houses at each end of the lane to the works, preventing the men from going to the classes. The boiler-houses would be more efficient to-day if the trained women were still employed. As regards testing coal, Mr. Fedden had analytical tests made, and he also had a spare bunker from which any particular kind of coal could be burned under special observation. He had samples from every hopper analysed every day, so that he had a continuous check on the nature of the coal being burnt. It seemed impossible to educate the mine owners sufficiently to make them understand that blackness alone was not a sufficient characteristic of coal. He did not like Government control, but he wished coal owners could somehow be forced to sell coal at a price depending upon its calorific value. In conclusion, he wished to emphasise the fact that the boiler-house was the place in a power plant where the greatest savings were possible, and it hardly mattered how much money one spent in getting good men and proper apparatus.

The chairman remarked that Sir Robert Hadfield was unavoidably absent, but had asked Mr. R. J. Sarjant to represent him. Mr. Sarjant said that Sir Robert, had he been present, would have emphasised his remarks made before Section IV of the Engineering Conference the previous day. He considered the Federation of British Industries were working on sound lines in promoting fuel economy. The firm with which he was connected had taken a wise course in buying their electric power from a large corporation,

Mr. David Brownlie agreed with Mr. Wilson in attributing boiler inefficiency principally to lack of proper control, brought about by the refusal to pay adequate salaries for the work. He had made a complete investigation of some 400 separate boiler plants, which consumed in the aggregate 3,250,000 tons of coal annually, and comprised 1,513 individual boilers, and covered 41 different industries. The average efficiency of these was only 58 per cent., including boilers, superheaters and economisers. The speaker had inspected 2,000 boilers with an annual consumption of 15,000,000 tons, and the average efficiency was less than 60 per cent. It was a disgraceful state of affairs that not 10 per cent. of the boiler plants in the country had water meters, not 1 per cent. had steam meters, less than 7½ per cent. had CO_2 recorders, and 25 per cent. had no economisers. As regards buying coal by analysis there was no desire to bind down any coal owner to supply coal of a definite calorific value under penalty of rejection, but merely to insist that the price should vary by a sliding scale in accordance with the calorific value of the coal.

Mr. Charles Erith said the difficulties of adequate supervision were great when installations were on a small scale. He disliked any form of control, but surely it was necessary in view of the kind of stuff sold by the mines. It was a scandal that London power stations should be called on to use coal of only 6,000 B.Th.U. per pound.

Mr. Appleby said he had found it pay to put combustion engineers into plants with only five Lancashire boilers. In one case a man had been sent to a plant with eight boilers, and by proper management he had been able to shut three of them down and give more than the former aggregate amount of steam from the remainder. Men on such work certainly earned their 400*l.* or 500*l.* per year. Mr. Wilson had mentioned 80 per cent. to 85 per cent. efficiency. The speaker would like to know how it was got, as he had not been able to exceed 76 per cent. even with modern plant.

Mr. Gill, of the South Metropolitan Gas Company, mentioned that that company had a number of hand-fired Lancashire boilers burning coke-breeze. To train stokers, a small battery of boilers had been used as a training school into which firemen were drafted for two or three weeks. When they returned to their own boilers their work was greatly improved, and they took much more interest in it. Gas works wanted good clean coal, and in the speaker's opinion it was essential that coal should be purchased on a sliding scale by which the price should vary with the quality. His company had retort-house inspectors in charge of carbonisation, and emulation among the various retort-house staffs to make the best showing, and to earn the right to fly the flag denoting the most efficient house, had brought about a high standard of operation.

Mr. Williams concurred with the author that efficiency could only be obtained by paying a proper salary to the staff. His firm insisted on periodical reports as to the cost per ton of steam generated, and they proposed to sell it by weight to the various departments using steam, so that the boiler plant should be put on a business basis, and people would understand that steam had a value per ton. The efficiency on their boiler plant had been raised to an average of 75 per cent. by proper supervision, and tests showing 80·5 per cent. had been obtained. The thing to do was to make the boiler-house superintendent prepare returns as to the cost per ton of steam.

Mr. F. C. Lea agreed that proper supervisors, liberally paid, were the means of promoting efficiency but where could such men be obtained? No college or technical school taught the proper running and maintenance of plant, they confined themselves to more abstract and theoretical aspects of engineering. A practical rather than theoretical training was necessary, to operate an engine or boiler plant properly.

Mr. McDonald, of the South Metropolitan Gas Company, referring to the point raised by Mr. Lea, said that they had had a retort house foreman whose health had prevented him continuing in that position. He had been put in charge of the boiler plants, and having added, by reading and study, to his previous practical knowledge, had easily earned his salary at his new job. He also went round to outside plants to teach people how to burn coke in Lancashire boilers, and had shown that it was possible to get better evaporation with coke than they had previously obtained with coal.

Mr. W. H. Patchell, chairman, said that in Detroit, where he had been last year, college graduates had been employed as supervisors in the boiler-room, and one of these men had risen to a very high position with the company. As regards cost of equipping boilers with appliances, such as CO_2 recorders, meters, &c., to promote economy, it was worth pointing out that the larger the boiler units, the less of such appliances were necessary.

The reluctance of mine owners to supply coal on the basis of its calorific value had been mentioned, but it was a fact that many years ago, when Mr. J. H. Rider was in charge of the London County Council plant, he had bought coal on such a basis.

Mr. David Wilson, in replying to the discussion, referred to the enormous and deplorable difference which often existed between test efficiencies and operating efficiencies. An efficiency of 85 per cent. on the net calorific value of the coal could be realised by keeping the losses down to the following figures. Flue gas losses, 9 per cent.; loss in ashes, 1 per cent.; radiation losses, 4 per cent.; unaccounted-for losses, 1 per cent. The Government ought certainly to do something as regards the grading of coal, so that it might be purchased by heating value rather than by weight.

Low-Temperature Carbonisation of Coal.

The next paper to be discussed in the Council Room, was that on "The Low-Temperature Carbonisation of Coal," but as the author, Professor W. A. Bone, D.Sc., F.R.S., was absent on account of ill-health, the chairman, Mr. W. H. Patchell, asked Dr. Eric Sinkinson, of the Imperial College of Science, to read it on behalf of the author.

It was pointed out in the paper that any fuel to supplant coal should be smokeless, easily transportable, and relatively cheap. Before the war, gas in Sheffield contained 580 B.Th.U. per cubic foot, and cost 2½*d.* per therm (100,000 B.Th.U.). London gas then contained 550 B.Th.U. per cubic foot and cost 5½*d.* per therm. The cost of gas-making has risen to such an extent that the gas companies were asking powers to raise their prices to 10*d.* or 20*d.* per therm in various places. With coal at 63*s.* per ton, a therm of coal heat cost only 2½*d.*, so that the use of gas for anything but cooking or doing occasional heating was in danger of becoming a luxury and the open fire for ordinary domestic heating was likely to continue. It was by low-temperature carbonisation that relief from the smoke nuisance was ultimately to be obtained. In this country the most comfortable source of domestic heat was by radiation from red-hot substances, and this could be obtained by raw coal for 2½*d.* per therm, by semi-coke, carbonised at a low temperature, for 3*d.* per therm, by gas at 15*d.* per therm, and by electricity at 60*d.* per therm, if electric power was available at 3*d.* per unit. The following table gave relative costs of the three methods:—

—	Electric Radiator.	Gas Fire.	Open Fire.	
			Raw Coal.	Semi-Coke.
Assumed radiant gross efficiency on gross efficiency of fuel	100	44	24	32
Assumed prime cost of fuel per therm (100,000 B.Th.U.)	60	15	2·5	3·0*d.*
Fuel cost per therm of radiation into rooms ..	60	34	10·4	9·4*d.*

The table shows that the consumer could get a given amount of heat in the form of radiation from coal or semi-coke at less cost than from gas or electricity. To procure a complete solution of the problem of domestic heating it would appear that we should revert somewhat towards the earliest gas-works practice which, by low-temperature carbonisation in iron retorts produced a rich gas and a soft coke. Low-temperature carbonisation also would render valuable assistance to our liquid fuel resources, for if coal were carbonised at 1,000 deg. to 1,100 deg. F., there could be produced from it 10 per cent. to 15 per cent. by weight of valuable oil, and from 3,000 cub. ft. to 4,000 cub. ft. of rich gas per ton, the semi-coke remaining being an almost ideal domestic fuel. Messrs. Porter and Taylor, of Pittsburg, who had investigated the results of carbonising coal at 800 deg. to 900 deg. F., found that from 0·6 cub. ft. to 0·7 cub. ft. of gas could be obtained per pound of coal, together with oil or tar equal to 10 per cent. to 12 per cent. of the weight of the coal. The author preferred a temperature of about 1,000 deg. F., as being the most generally suitable.

Dr. Cecil Lander, who opened the discussion in place of Dr. Beilby, who could not be present, said that the report of the Fuel Research Committee now in course of preparation would show that the work of the Fuel Research Station was very varied, but was mainly directed to getting accurate thermal and weight balance sheets for different coals. Samples of commercial size, namely, 2 cwt. at a time, were carbonised in horizontal steel retorts heated by water gas and weight balances obtained within 1 per cent. About 120 different coals and mixtures of coal had been tested. At the same time laboratory assay methods were developed so successfully that now it was possible to predict from laboratory analysis of small samples exactly what would happen when coal in bulk was dealt with. Dr. Lander exhibited curves, showing that when coal was distilled at any temperature at first there was a rapid evolution of gas, the rate of emission rising to a maximum peak and then quickly falling off. Such curves indicated the time beyond which further distillation was useless. Samples of semi-coke prepared at the Research Station were handed round for examination. The Research Board had always in mind the question of cost, but exact experimental work, such as that carried out, could not be on a commercial basis. Indeed the costs at Greenwich were 15*s.* per ton for labour alone.

Mr. Wilkin, of Connersville, U.S.A., was then called upon by the chairman. He said that in the States similar work directed towards the solution of the problems of low-temperature carbonisation, was being carried on, but unfortunately he was not cognisant of the latest results, so that he could not give them to the meeting. He felt that in considering the future of the domestic fuel problem, we ought to remember that even if raw coal were cheaper in first cost than semi-coke, the public had to pay for its use a heavy annual sum in respect of repainting, refurnishing and washing, which the use of semi-coke would avoid. These costs should be taken into account in making comparisons.

Dr. R. Lessing said he had been interested in low-temperature carbonisation for many years. Practical success was impossible until the scientific foundation of the process had been thoroughly explored. We were not much nearer understanding what coal really was, than we were sixteen or eighteen years ago. Our ignorance about coke was indescribable and many more investigators were required. At the Greenwich research station they were endeavouring to get the necessary data to permit of practical application of the process on a large scale. With high-temperature distillation one had a steep temperature gradient which was favourable for getting heat into the retorts, but the length of time required to effect the process of distillation at low temperature, on account of the small heat gradient, was one of the great difficulties.

Mr. David Brownlie said that what engineers really wanted to know was the cost of making coalite, or semi-coke. Could the author give any definite data on the matter. What was being done with the Smith carbo-coal system, or the Maclaurin system, which also were based on low-temperature distillation? The latter, the speaker believed, depended on internally-fired retorts something like beehive ovens with recovery plants.

Mr. Sarjant said every sympathy was due to people who pioneered in any industrial process. The low temperature carbonisation plant at Barugh, near Barnsley, was in the pioneer stage. The plant there had vertical retorts fitted with hanging internal perforated plates which permitted the expansion of the coal when forming coke. The coke produced was dumped from the lower end of the retorts and burnt under waste heat boilers, the steam being used for by-product work. He had left the plant with the idea that the staff there were trying hard and were very hopeful as to the future of the process.

Mr. G. N. Gill, of the South Metropolitan Gas Company, said that as a gas works engineer he could not look very hopefully on the low temperature process. As a carbonising proposition its outlook was poor. The capital charges, maintenance and heating costs of a retort house were heavy, and the output of gas by the low temperature process was so small that the cost of the gas would be excessive. The gas makers tendency was towards the coke-makers practice, namely, to distill coal in quantities of tons at a time. This was impossible with low temperature working as there was too great difficulty in getting the heat into the coal. Low temperature distillation involved the coal being used in thin layers, which involved a large plant and a slow method of working.

Mr. E. R. Dolby pointed out that the original method of making "Coalite" depended on the use of vertical cast iron retorts. It now appeared from the remarks of the last speaker that the best scheme was to heat the coal in thin layers. Was the vertical cast iron retort found unsatisfactory?

Mr. Sargant said that with regard to this point he should have made it clear that at Barugh vertical rectangular retorts were used.

Mr. C. M. D. Belton said that the pertinacity of the investigators of low temperature carbonisation deserved praise, but up to the present such carbonisation was not a commercial proposition. He did not think that gas works need be frighened at the prospect before them. The talk about the dangers of gas containing 30 per cent. CO was merely the raising of a bogie, such gas was desirable for many purposes. In the end everything came back to the commercial results which could be obtained by any process. An output of 3,000 cub. ft. of gas per ton of coal carbonised was of no use at all to gas engineers.

The Chairman, on calling on Dr. Sinkinson to reply to the discussion, reminded the audience that they must not forget the object of any particular process. Was it devised primarily for the production of smokeless fuel, gas, or by-products? In other words, what was to be considered the main output and what the by-products? Not all the coal in Great Britain could be coked, but if all the coal which was capable were to be turned into coke there would not be enough railway wagons in the country to transport the product.

Dr. Eric Sinkinson, in his reply, said that the difficulties of getting heat into a mass of coal in order to coke it were very great as the thermal conductivity of coal was so slight. In many low temperature processes there had also been difficult in working on account of the increase in volume of the coal produced by coking. He had seen men hammering away for hours to get the stuff out of the retorts. However, whatever the difficulties might be he wished to emphasise the point that a therm in the form of coal cost 2½*d.*, in the form of gas it cost 1*s.* 6*d.*, while in the form of semi-coke it cost only 3*d.* He disagreed with the view that C.O. in the gas supplied by the companies was harmless. It caused headaches and other troubles, but these were not suffered by the gas company who, therefore, regarded them lightly. The domestic fuel of the future should be something that could be burnt smokelessly in open grates, so that the radiant heat might be enjoyed. Coal had many good points, but the conscientious householder in burning it did not like to feel that he was burning up sulphate of ammonia, oils, and other extremely valuable products with practically no benefit to anybody.

Engine-House Management and Steam Engine Inefficiency.

The first of the two papers delivered before the members assembled in the Committee Room at the Institution, on Thursday, June 30, under the chairmanship of Mr. F. H. Livens, dealt with the question of engine-house management and the general causes of steam-engine inefficiency. In his opening remarks the author, Mr. Hubert Dunell, pointed out that there were two distinct classes of loss in the engine-house, the first being the wastage of steam before it gets to the engine and the second the inefficient use of steam in the engine itself. In dealing with the former, Mr. Dunell emphasised the importance of steam leakages due to defective joints. Such leakages, when small, were apt to be disregarded, but a number of small leakages might, in the aggregate, become a very serious source of wastage. This was particularly liable to occur where superheated steam was used, and where as a consequence the leak was not visible. Proper jointing and the reduction of stresses and vibrations in the joints by proper design and by the use of expansion

bends, would largely diminish the tendency of the steam mains to start leaks.

Losses in the steam mains through condensation was, the author stated, a serious source of inefficiency in many small plants. Such losses could be minimised by insulating the pipes properly and by so arranging the valves that the steam could be circulated right round the mains during periods of light load, in order to keep them warm. As regards insulation, magnesia was to be strongly recommended owing to the fact that 2 in. of this material would retain some 93 per cent. of the total heat in the main.

Steam traps were another source of direct loss. In practice it is usually found that they either passed live steam or allowed the pipes to become waterlogged. For intermittent draining purposes plug cocks were to be preferred, a man being delegated to go round periodically and open them until steam appeared. Where a steam trap was absolutely necessary, as in connection with steam separators, the float type probably gave the best results, although on a low-pressure separator an inverted syphon might be substituted. Traps of any type called for constant attention and should have a visible discharge.

In considering the question of the maintenance of the engines in an efficient condition, the author pointed out that while steam turbines, and especially those of the reaction type, called for little attention, reciprocating engines demanded more frequent examination. He cited an instance in which the first indication which he received that the high-pressure piston rings had broken and found their way into the exhaust pipe was by means of indicator diagrams, and another case in which the low-pressure piston valve had shed a large piece of its lap without detection until the diagrams came to be examined. Both these engines had been working inefficiently, but appeared to be running satisfactorily. These two somewhat extreme cases served to illustrate the necessity of indicating engines periodically in order to ascertain if any serious defect had been developed.

Referring to mixed-pressure installations, Mr. Dunell pointed out that in plants of this nature the engineer was faced with all the troubles incidental to both turbine and reciprocation engine installations, with a whole train of additional ones thrown in. Of the latter not the least was the prevention of the oil from the cylinders of the reciprocating engine being carried over to the turbines in the exhaust. Oil thus reaching the turbine caused a most tenacious deposit on the blading, the most effective method of removal being to mount the rotor over a tank of paraffin oil and give it a good soaking. A jet of wet steam would then blow most of the deposit from the blades.

Another part of the plant upon which the economical working of the whole depended to a considerable extent was the condenser. The author emphasised the necessity of a good vacuum in connection with reciprocating engines, and its still greater importance in the case of turbines. With the latter a loss of 1 in. of vacuum might result in an increase of from 6 per cent. to 7 per cent., in the steam consumption. It was therefore essential that surface condensers should be kept clean. There appeared to be a critical depth of scale which, when deposited on the tubes, induced the rapid deposit of further scale. Before the critical stage was reached, the scale could be removed fairly easily by hand, but subsequently all kinds of gear were required to get it off. Hydrochloric acid was sometimes used for this purpose, but this treatment was so drastic as to render essential in its employment extreme caution. Warm caustic soda solution, circulated by means of a small pulsometer pump, had been effectively used by the author in removing scale from the tubes of an economiser, and the same method might be applied to condenser tubes. A further suggestion, based on the experience of the steamers plying on the Yangtse River, was the introduction at intervals of a certain amount of sand into the circulating water in order to scour the scale from the condenser tubes.

The use of excessive circulating water under conditions of light load was another source of waste. Not only did it entail the use of unnecessary power in pumping the water, but it also carried away heat that might have been retained in the hot-well.

In concluding his paper, Mr. Dunell strongly advocated the occasional running of tests under working conditions, and expressed the opinion that such tests were of much greater value than daily records, which were seldom properly kept and rarely inspected. Such tests, if carried out under proper conditions and on isolated units of the plant, would indicate the true condition of the machinery involved. The condensate of each unit could be measured, or, as an alternative, steam meters could be installed. The latter method was, however, subject to criticism on account of the high first cost of the meters, and of the fact that their indications were considerably complicated by varying conditions of pressure, superheat and the volume of steam dealt with.

In opening the discussion on Mr. Dunell's paper, Mr. G. T. Gillespy pointed out that there was a wide range of pipe coverings available between clay and cow-dung at the one extreme and magnesia at the other. He also questioned the meaning of the statement regarding the efficiency of the latter material, and indicated that any statement as to the amount of heat retained by any form of insulation could not be accepted as scientific data, since such amount would be dependent on the length of the steam pipe and on other factors of a variable nature, as well as upon the nature of the covering.

Mr. S. G. Martlew emphasised the importance of the lay-out of the main steam pipe-lines, of properly designed expansion bends, and of the avoidance of blasts of cold air striking on the pipes. He depreciated Mr. Dunell's remarks regarding drainage, and expressed the view that some automatic device was to be preferred to the alternative of entrusting this work to an attendant. In connection with steam turbines, Mr. Martlew advocated the use of superheated steam as the surest way of avoiding damage to the blading through the action of water, and the employment of oil separators in order to eliminate the oil.

Mr. E. Edwards took issue with the views expressed by the author of the paper regarding the relative value of periodical tests and daily records. He pointed out that the losses which occurred outside the engine were usually much greater than those which occurred within the engine itself, and for this reason a continuous record was of more value than an occasional indicator diagram. He cited one instance in his own experience illustrative of the potential losses in connection with steam traps. In a certain plant a number of these discharged under ground, and by simply re-arranging them so that they discharged above ground 1,000 tons of coal per annum was saved. It would need to be a very serious engine defect to cause an equivalent wastage of fuel. Mr. Edwards also advocated the installation of steam mains in shallow trenches packed with fossil meal as the most effective method of insulation. Referring to the difficulty of oil getting into the turbine in mixed-pressure plants, he stated that by using an oil separator in conjunction with three Lancashire boilers, the oil was completely eliminated. In a subsequent description of this arrangement, Mr. Edwards explained how the steam was led through the separator, after leaving the reciprocating engine, into the first of the Lancashire boilers, in which all the oil which the separator failed to eliminate from the steam was deposited. The steam was then led into the second boiler, in which it was discharged below water level, the steam being withdrawn from the opposite end and passed to the third boiler, where the process was repeated. The boilers acted as steam accumulators to damp out fluctuations in the steam supply coming from the reciprocating engine. They were about three parts filled with water, the temperature of which varied under ordinary working conditions from 217 deg. F. to 219 deg. F., the steam pressure being about 2 lb. per square inch above atmospheric pressure. With this arrangement no trouble whatever was experienced due to oil reaching the turbine.

Mr. D. Halpin referred to the value of cork as an insulating material, and pointed out that its cellular structure rendered it of great value in the prevention of radiation from steam pipes.

Mr. S. G. Martlew, referring to the use of sand in the circulating water as a means of cleaning condenser tubes, pointed out that this practice was not to be recommended, as it choked the circulating pumps and tended to wear the tubes. He also expressed the view that in moderate degrees of superheat might be found a solution to many of the difficulties met with in steam power plants. The utilisation of exhaust steam was another matter which had not so far been mentioned, but which deserved consideration. He maintained that in many cases in which heat was required for process work it would pay to make the plant non-condensing rather than to condense the exhaust steam, so that the latter might be available for heating purposes.

In replying to the various points raised during the debate, Mr. Dunell pointed out, in supporting plug cocks as opposed to steam traps, that steam pipes were always inclined to give off scale, and that this was very liable to get into the traps and put them out of action. Referring to indicator diagrams, he argued that since the indicated steam consumption could be obtained from such diagrams, and the actual steam consumption of the plant from measuring the feed water, a properly conducted test would give not only the quantity of steam used by the engine but also the amount due to losses external to the engine.

SUPER-COMPRESSION AND THE ECONOMY OF THE INTERNAL COMBUSTION ENGINE.

The second paper, which was read by Mr. A. E. L. Chorlton, C.B.E., dealt with "Super-Compression and other Means for Improving the Economy of Internal Combustion Engines." He pointed out that the pressure of release in the internal combustion engine was usually about 40 lb. per square inch, and the loss of power in dissipating this direct to the atmosphere without doing any further work had led to many attempts to obtain an increased degree of expansion with consequent gain in economy.

TABLE I.

Normal Running.

Experimental supercharging engine: 110 mm. bore by 150 mm. stroke. Compression ratio 5·0 : 1.

B.P.M.	Maximum B.H.P.	Maximum B.M.E.P.	B.M.E.P. at Most Economical Load.	Fuel. Pounds per B.H.P.	Fuel. Pounds per I.H.P.	Indicated Thermal Efficiency.	Relative Efficiency.
				per hr.	per hr.	per c.	per c.
1,000	11·2	106	103—105	0·525	0·475	28·6	60·3
1,200	13·5	108	104—106	0·510	0·455	29·9	63·0
1,400	15·9	109	105—107	0·501	0·443	30·7	64·6
1,600	17·9	108	104—106	0·502	0·44	30·9	65·0
1,800	19·7	105	101—103	0·515	0·438	31·0	65·3
2,000	20·6	99	95— 97	0·535	0·440	30·9	65·0
2,200	20·5	90					
			Supercharging.				
1,000	14·7	140	110—135	0·483	0·434	31·4	66·2
1,200	18·0	143	112—137	0·465	0·416	32·7	68·8
1,400	21·2	146	115—140	0·461	0·408	33·4	70·3
1,600	24·6	148	115—142	0·459	0·402	33·8	71·3
1,800	27·5	146	115—140	0·461	0·400	34·0	71·6
2,000	29·6	141	112—136	0·470	0·405	33·7	71·0
2,200	30·5	133					

TABLE II.—*Stratified Charging. Results of Experiments made on a Large Gas Engine.*

Two-stroke cycle-light load-slow speeds.

Date.	Average B.T.U. per I.H.P. Hour.	I.H.P.	Mean Effective Pressure.	R.P.M.	Indicated Thermal Efficiency
					per cent.
2·7·13	5,620	83·5	30·4	87·0	45·2
3·7·13	5,800	83·2	31·4	87·0	43·8
3·7·13	6,020	81·7	29·9	87·0	42·2
3·7·13	5,930	87·0	31·0	89·0	42·8
Average	5,843	83·8	30·7	87·5	43·5

Approximate contents of working cylinder :—
Volume of cylinder = 8·49 cub. ft.
Volume of mixture = 3·44 cub. ft.
Volume of exhaust products = 5·05 cub. ft.

In one method this was carried out by varying the piston travel during successive strokes by the use of suitable mechanical devices, such as Atkinson's link motion. (See Figs. 3 and 4 on page 70).

With regard to compounding, *i.e.*, using the pressure of release in a second cylinder as against the use of a longer expansion stroke in one cylinder,

SUPER-COMPRESSION IN INTERNAL-COMBUSTION ENGINES.

Fig. 3. ATKINSON LINK MOTION.

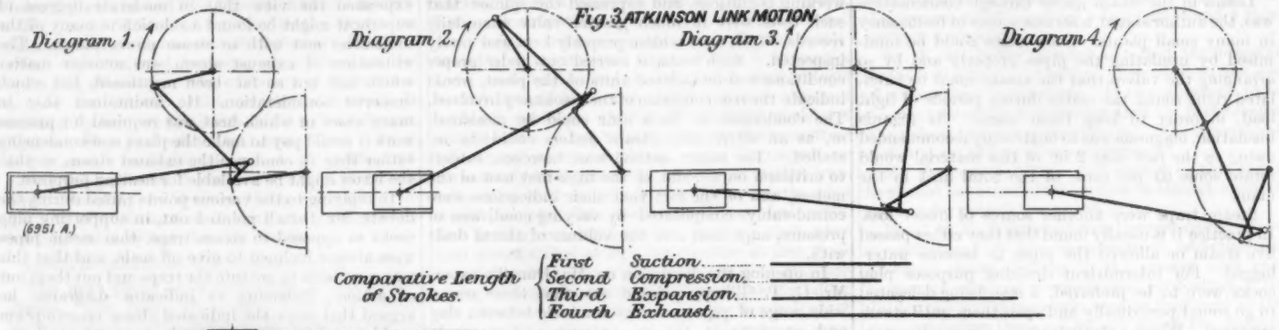


Fig. 5. COMPOUND INTERNAL COMBUSTION ENGINE. CLERK 1904.

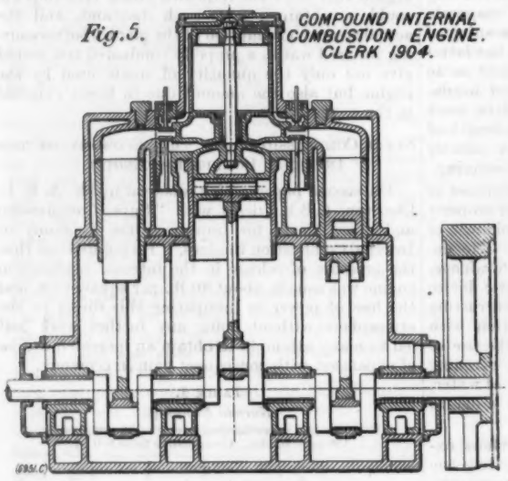


Fig. 6. COMPOUND INTERNAL COMBUSTION ENGINE. JUNKERS 1906.

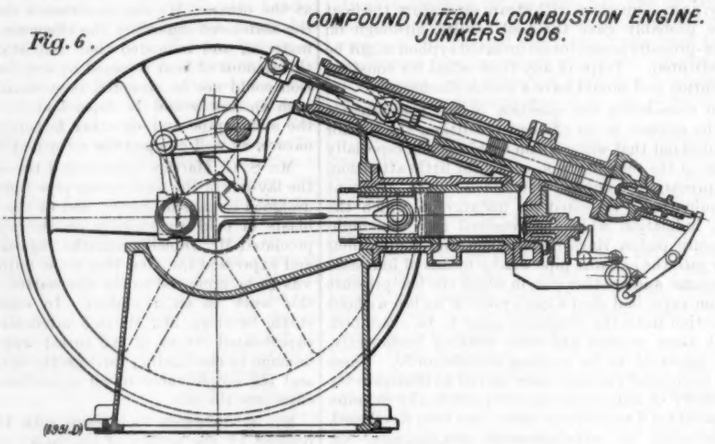


Fig. 4. ATKINSON CYCLE ENGINE. (PROF. UNWINS DIAGRAM).

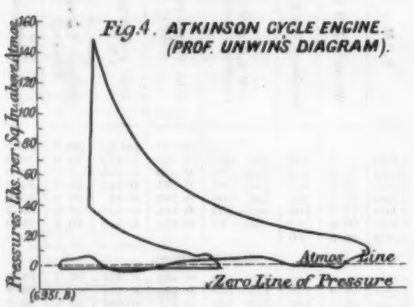
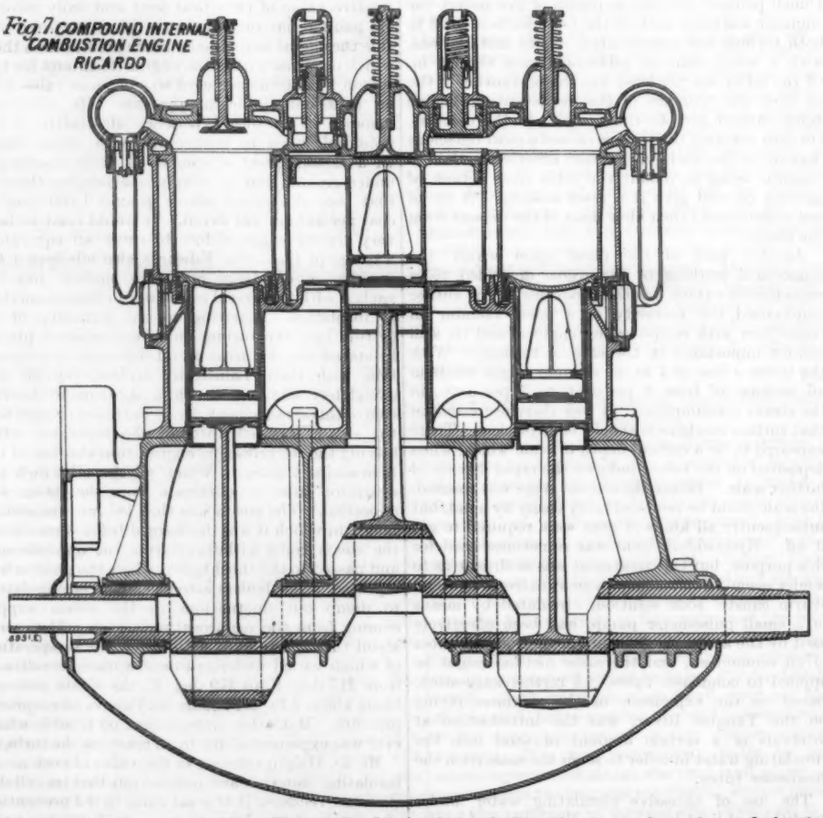


Fig. 7. COMPOUND INTERNAL COMBUSTION ENGINE RICARDO



many attempts have been made to build engines of this type, but so far with little success; the difficulty has always been the loss of heat in the transference of the working fluid to the low-pressure cylinder. (See Sir Dugald Clerk's engine, Fig. 5, Junker's engine, Fig. 6, and Ricardo's engine, Fig. 7.)

Extended expansion in a normal cylinder is effected by late closing of the inlet valve during the compression stroke. The disadvantage of this method is that it has a corresponding effect on the compression pressure.

It is well known that economy is increased by raising the compression ratio above present ratios; but means must be adopted to overcome the pre-ignition and other heat difficulties to which the engine becomes liable. The addition of cooled exhaust products is the preferred method which enables the compression ratio to be raised, or less suitable gases or fuels to be used. Ricardo has made many exhaustive experiments, the results of which were given in a paper recently read before the Institute of Automobile Engineers.

Supercharging, though frequently discussed, has so far been very little used; it is undoubtedly likely to be employed in the future both for economy and increase of power. Cooled exhaust products aid in the economy and the additional air in the power. Sir Dugald Clerk brought out his engine in 1902, and obtained an increase in indicated thermal efficiency of 5·7 per cent. see (Figs. 8 to 10). Ricardo has with a modified form obtained quite good results which have been published recently.*

As applied to the two-cycle engine and showing the capacity of carrying overloads, the diagram from Junker's two-cycle engine, Fig. 13, is interesting; this is obtained by throttling the exhaust and

* See ENGINEERING, May 27, 1921, page 652.

SUPER-COMPRESSION IN INTERNAL-COMBUSTION ENGINES.

Fig. 8. DIAGRAM OF SUPER-COMPRESSION ENGINE. (CLERK.)

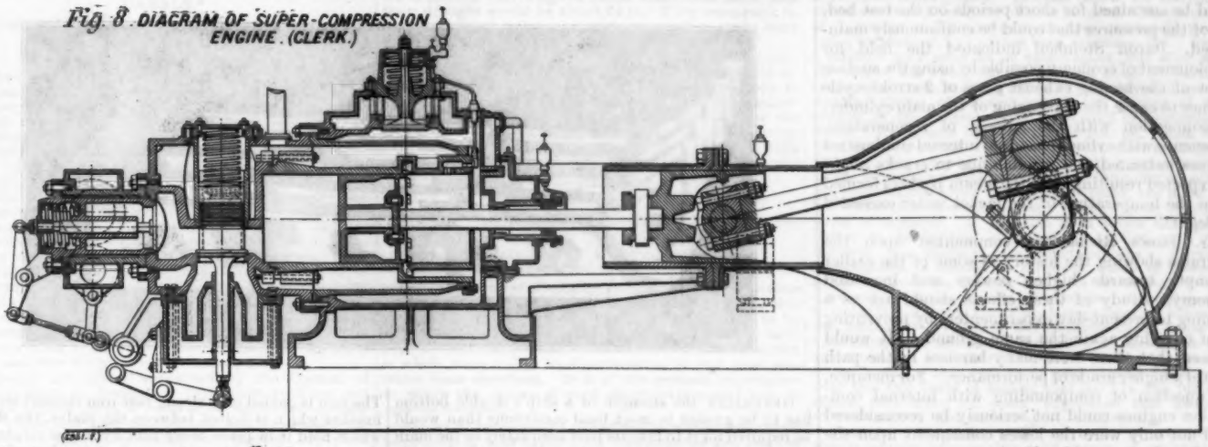


Fig. 9. CYLINDER OF CLERK SUPERCOMPRESSION ENGINE (1902).

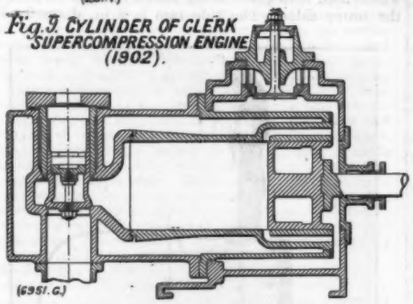


Fig. 11. APPROXIMATE CONTENTS OF WORKING CYL.
Volume of Cylinder ..... 8·49 Cu. Ft.
" " Mixture ..... 3·44 " "
" " Exhaust Products 5·05 " "

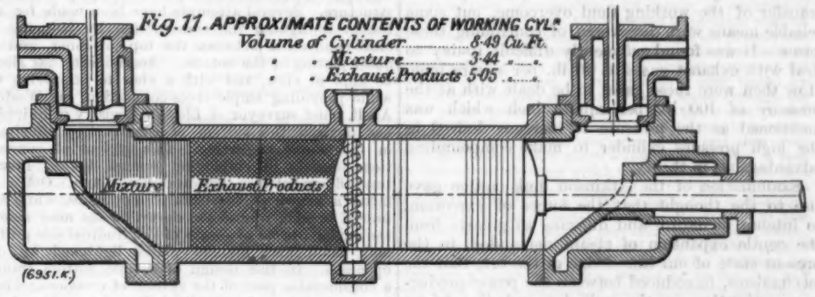


Fig. 10. ORDINARY DIAGRAM WITHOUT ADDED AIR.

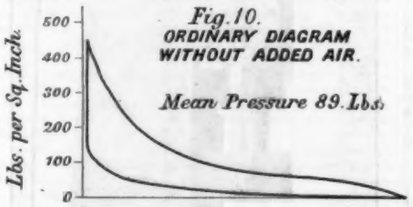


Fig. 12. SECTION OF CYLINDER SHEWING INTERCOOLER. 1904.

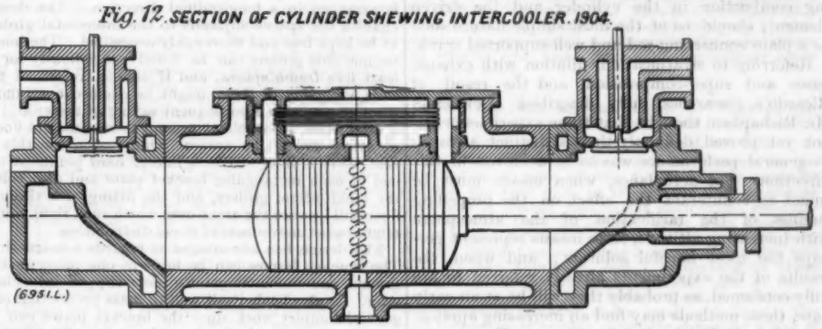


DIAGRAM WITH ADDED AIR.

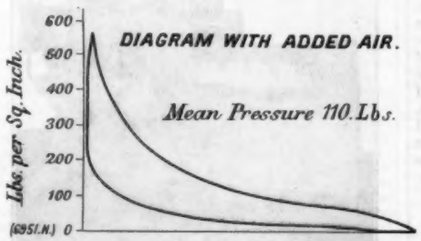


Fig. 13. COMBINED DIAGRAM OF TEST ON JUNKERS' COMPOUND ENGINE.

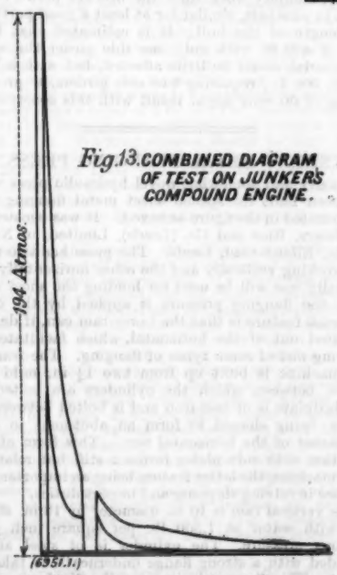
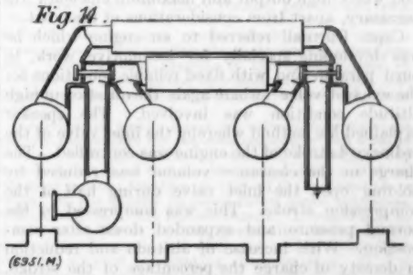


Fig. 14.



by using extra large supply pumps to give the supercharge of air.

Table I, page 69, shows the results got by Mr. Ricardo comparing normal running with supercharging. The idea of stratified working is a very old one, and was first raised by Otto and his supporters in an attempt to show that in the original Otto engine, and also in early two-cycle engines, there existed at the moment of ignition a layer of inert gas in the neighbourhood of the piston and an active mixture against the igniter, with air between.

Table II, page 69, gives results obtained by the author in 1913. "The engine in this case was a large one and the speed low, which allowed the stratification to be carried out with more than usual accuracy. The form of the cylinder end and the relative positions of the mixture and the burnt products are shown in Fig. 11, annexed. Fig. 12 shows a similar engine with the addition of an intercooler, proposed in 1904, and Fig. 14 illustrates diagrammatically a method of introducing exhaust gas from one cylinder to another."

The great loss of heat to the jackets and by the exhaust has directed the attention of many designers to methods of conserving it. In stationary engines it has been proposed to employ the jacket water and exhaust heat to raise steam. In the Still engine the cylinder heat is utilised by employing the generated steam on the other side of the internal combustion engine piston. There is no doubt that increased economy can be obtained in this way, but experimental work is required.

The discussion on Mr. Charlton's paper was contributed to by Mr. Wimperis, who elaborated certain points concerning stratification and supercharging. Mr. E. W. Petter, who followed, emphasised the fact that no new lines of development which might raise hopes for increased economy had been opened up. Baron George Steinheil, B.Sc., stated that in Germany a Diesel engine of considerable size running at 183 r.p.m. giving a mean effective pressure in the cylinder of 200 lb. per square inch had been recently tested. It was understood that the mechanical efficiency was low. The obtaining of

this high mean effective pressure was discussed, and it was stated that knowledge was primarily required, not of the mean effective pressures that could be sustained for short periods on the test bed, but of the pressures that could be continuously maintained. Baron Steinheil indicated the field for development of economy possible by using the suction effect of the issuing exhaust gases of 2-stroke cycle engines to cause the scavenging of the main cylinder. In connection with the subject of regeneration, experience with cylinder heads of internal combustion engines indicated that trouble due to cracks might be expected resulting from the steam pockets formed when the temperature of the jacket water exceeded 80 deg. C.

Mr. James Richardson commented upon the diagrams showing the history of some of the earlier attempts towards higher powers and increased economy. Study of these efforts should act as a warning to present-day experimenters by preventing them covering again the same ground. It would be seen that there were many barriers in the path toward a higher grade of performance. For instance, the question of compounding with internal combustion engines could not seriously be reconsidered until not only were the losses consequent upon the transfer of the working fluid overcome, but some reliable means were discovered of controlling these gases. It was found sufficiently difficult to-day to deal with exhaust gases at 40 lb. per square inch. How then were these gases to be dealt with at the pressure of 100 lb. per square inch which was mentioned as the pressure of increase desired in the high pressure cylinder to make compounding advantageous in theory.

Examination of the Atkinson link action gave rise to the thought that the forces of explosion, so intense in nature and differing so greatly from the gentle expansion of steam, demanded, in the present state of our knowledge of the art, that the mechanisms, introduced between the power-producing combustion in the cylinder and the driven element, should be of the most simple nature such as a plain connecting rod and well-supported crank.

Referring to stratification, dilution with exhaust gases and super-compression, and the result of Ricardo's researches, fully described elsewhere,* Mr. Richardson thought that these experiments had not yet proved definitely that a distinct advance in general performance was to be achieved in this direction. For aeroplanes, when means must be found to counteract the effect on the propelling engines of the rarification of the atmosphere with increasing altitude, these means represent perhaps the most hopeful solution; and when the results of the experiments already referred to are fully confirmed, as probably they will be at an early date, these methods may find an increasing application where high output and maximum efficiency are necessary, apart from considerations of first cost.

Capt. Durtnall referred to an engine which he was developing specially for locomotive work, to burn paraffin and with fixed reliable conditions for the exhaust valve—where again the question of high altitude condition was involved. The speaker explained his method whereby the inlet valve of the ordinary 4-stroke of the engine was controlled. The charge in the clearance volume was reduced by holding open the inlet valve during half of the compression stroke. This was compressed to the normal pressure and expanded down after combustion. With increase of altitude and reduction in density of charge the percentage of the stroke, during which the inlet valve was kept open, was increased and so the power was maintained.

The proceedings of the Institution of Mechanical Engineers Summer Meeting were continued on Friday, the 1st inst., and the report of the discussions on that day will appear in our next issue.

(To be continued.)

THE BIRMINGHAM METALLURGICAL SOCIETY.—We are asked to state that this society's registered office is now Chamber of Commerce Buildings, New-street, Birmingham, and that Mr. A. C. Craig succeeds Mr. Thomas Vickers as secretary.

* See ENGINEERING, vol. cx, pages 325, 361, *Ibid.*, vol. cxi, pages 28, 57, 652.

IMPROVEMENTS IN DOUBLE BOTTOMS OF SHIPS.

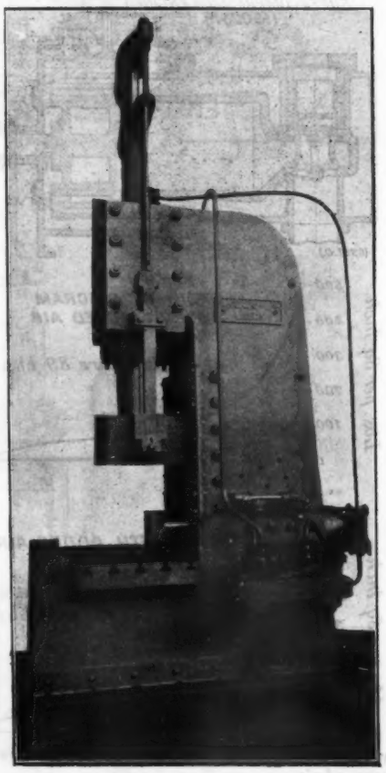
GENERALLY the strength of a ship's double bottom has to be greater to meet local conditions than would be required for it to take its part adequately in the main structure. Several attempts have been made for this reason to lighten the construction by reducing the cross-connection between the top, or inner, and the outer plating of the bottom. Accessibility has also to be kept in view, and with a view to improving this while providing ample cross-connection, Sir Westcott Abell, chief surveyor of Lloyd's Registry of Shipping, has devised the system of construction illustrated in the above engraving. This system of construction consists in employing several braced bracket frame floors between lightened plate floors. One of the latter is shown at the back of our figure, while four braced bracket frames are shown on the near side of the model, braced by means of longitudinal side girders, and rectangular bracket plates lightened by oval openings. In this design of double bottom framing a considerable part of the system of cross-connections is arranged in a longitudinal direction. The design enables the spaces adjacent to the intercostal girders to be kept free and thoroughly accessible. The longitudinal side girders can be fitted continuously for at least five frame spaces, and if double riveted at the ends a portion of them might be deemed continuous throughout, with a consequent saving of material. It is considered advisable at present to retain solid floors at every five frame spaces. One reason for this is that there is likely to be a line of hard points at the end of each rectangular bracket plate and also below the longitudinal girders, and the fitting of a through floor will localise the areas over which such rigid points might cause unevenness of stress distribution.

The design has advantages as regards construction. The bracket frames can be built in one piece on the ground and the intercostal girders slipped into place later. It also lends itself well to mass production and general templet work since the bracket plates can be made in numbers, similar for at least a good portion of the length of the hull. It is estimated that for a ship of 400 ft. with only one side girder the weight of material would be little affected, but with a larger vessel, 500 ft., requiring two side girders, a probable saving of 50 tons might result with this construction.

SHEET METAL FLANGING PRESS.

A NEAT and somewhat novel hydraulic press which has been built for special sheet metal flanging work is illustrated in the figure annexed. It was constructed by Messrs. Rice and Co. (Leeds), Limited, of Neville Works, Elland-road, Leeds. The press has two rams, one working vertically and the other horizontally, and normally one will be used for holding the sheet down while the flanging pressure is applied by the other. A special feature is that the lower ram can, if desired, be tilted out of the horizontal, which facilitates the carrying out of some types of flanging. The frame of the machine is built up from two 1¼ in. mild steel plates, between which the cylinders are bolted up. The bedplate is of cast-iron and is bolted between the plates, being shaped to form an abutment to resist the thrust of the horizontal ram. This form of construction with side plates forms a stiff but relatively light machine, the latter feature being an important one in cases involving shipping and import duties.

The vertical ram is 10 in. diameter by 18 in. stroke, and with water at 1,500 lb. per square inch gives 50 tons pressure. The cylinder is of steel and is provided with a strong flange underneath to take the thrust. This flange also carries the tie bars, which form a dead stop for the ram to prevent accidents. The ram is guided on a strong cast-iron channel section bracket which is bolted between the plates, the strips which hold it in place being held by angles riveted to the frame sides. The side ram is 8 in. diameter by



15 in. stroke and gives a pressure of 30 tons. This ram, as shown in the figure, is mounted horizontally, but the holes to which the mounting bolts are moved when it is desired to place the ram in an inclined position can be clearly seen. The valves are of the quick-acting metal-seat type.

QUEENSLAND'S MINERAL WEALTH.—A report just issued by the Queensland Government shows that the value of last year's mineral output in that State was 3,462,214*l.*, an increase of 990,187*l.* on the preceding year. The copper yield was valued at 1,551,995*l.*, while 1,109,913 tons of coal, worth 841,551*l.*, was mined, the figures constituting a record. The value of last year's gold yield was 489,701*l.*, a decrease of 24,402*l.* compared with 1919. Attention is called to the success attending the operations of Clark's Gold Mines, Limited, Charters Towers. At the company's mine a mill was completed in the course of the year, work both underground and on the surface was pushed ahead as fast as possible, and 2,445 tons of ore were raised and crushed, giving the return of 6,020 ozs. of smelted gold. At the close of the year the cyanide plant had treated 920 tons of sand for bullion valued at 5,025*l.*

THE INSTITUTION OF CIVIL ENGINEERS. ENGINEERING CONFERENCE.

SECTION II.—HARBOURS, DOCKS, RIVERS AND CANALS.*

REINFORCED CONCRETE FOR WHARVES AND BREAKWATERS.

By GERALD FITZGIBBON, M.Inst.C.E.

In the early years of this century the increasing scarcity and cost of suitable timber for wharf and jetty construction, coupled with the rapidly increasing size and draught of vessels requiring accommodation, favoured the adoption of reinforced concrete, which had not previously been made use of in dock or harbour works; and a number of important works were carried out in that material in this and other countries. The earliest examples of reinforced concrete as applied to dock or harbour works in the United Kingdom seem to be the construction at Liverpool of a cattle wharf deck on greenheart piles at Princes Jetty 1899–1900, and the decking of a wharf at the Coburg Dock in 1900. The first really extensive works in reinforced concrete in this country as applied to dock and harbour work were probably the coaling jetty at Southampton, 1901–03, and Purfleet Pier, 1903–04. Other important works in this country followed during the next few years, including Rochester Coal Wharf, 1906, the Thames Haven Jetty Head, and the Kings Dock, Swansea, 1907–09.

A special committee appointed by the Council of the Institution in December, 1908, took evidence and obtained reports upon a number of reinforced-concrete works which had been carried out, and the results are embodied in their Preliminary and Interim Report of June, 1910, and their Second Report of July, 1913. From these reports it would appear that in the earlier examples of reinforced concrete as applied to dock and harbour works certain defects had manifested themselves, such as rusting of the steel reinforcement causing the concrete covering to crack and burst off. These defects were worse at the junctions of main and secondary beams of decking, and at junctions of beams and bracing with piles, where reinforcing bars interlaced, making it difficult to embed the bars solidly. Voids being left in the concrete, water percolated in and out through the concrete skin. In some cases the rusting of the reinforcement and the splitting of the concrete was very extensive. These defects were apparently due to faults in design or construction and did not deter engineers from availing themselves of the advantages offered by the use of reinforced concrete.

The features of the design of the works already mentioned are well known. They consist generally of a system of decking, main and secondary beams, rows of single piles or groups of piles, and bracing. In some cases there are in the front row groups of two or more piles surrounded by reinforced-concrete cylinders let down around the piles. Above low water, in the case of tidal work, the structure is tied and strutted by a system of bracing incorporated with the piles and deck beams. Under water, bracing in reinforced concrete is difficult, if not impossible, and the author is not aware of its having been successfully attempted. A suggestion was made to the Committee on Reinforced Concrete that the difficulty might be overcome by casting a horizontal brace, having a length of cylinder at each end, and lowering it down over two pile clusters. Some such method might probably be practicable. It might even be possible to cast a complete panel of horizontal and diagonal bracing, with the necessary lengths of cylinder, and to lower it down over the pile clusters.

In some cases cross walls of sheet piling have been driven between front and back piles, the heads of the sheet piles being incorporated with the horizontal cross ties.

At the King's Dock, Swansea, opened in 1909, where nearly 1,000 lineal yards of reinforced-concrete quays were constructed, the work being executed in the dry, it was possible to adopt a different design to that generally in use. The quays are divided into bays of about 30 ft., with front and back columns 4 ft. 6 in. square, which are under the movable coal hoists. Behind the columns are two rows of piles, the back row forming part of the curtain wall which retains the embankment. The columns are strutted and braced longitudinally and transversely down to 10 ft. below the water-level in the dock, and the frontage is protected by horizontal and vertical elm fendering.

Some very important reinforced-concrete work has been executed recently in the Port of London, including the jetties at the Royal Albert Dock Extension (South) and the Tilbury Ocean Wharf.

The author suggests for discussion the possible advantages of the caisson method of construction for deep-water wharves and breakwaters, both as regards economy in cost and time of construction. This method has been successfully adopted in Denmark at Nörre Sundby, Jutland, where reinforced-concrete caissons, 32 ft. long, 17 ft. wide, and 26½ ft. deep, were built on land, launched, towed to their positions, and sunk in the line of the wharf of which they formed part. At Copenhagen the walls of the recently completed Kronelöbs Basin, 31 ft. at low water, were formed of reinforced-concrete caissons, built in dock, floated into position, and sunk on a prepared foundation. Each caisson was about 160 ft. long, 16½ ft. wide, or with toe and heel 23 ft., and 32 ft. deep. Island breakwaters, to shelter the harbour, were also constructed on the same principal. At Valparaiso, Messrs. S. Pearson and Son are at present carrying out works, including a breakwater, the submerged portion of which is formed of reinforced-concrete caissons, 65 ft. long, about 50 ft. wide, and 49 ft. deep, which are built in a temporary dock, floated out, towed into position, sunk, and filled with concrete from barges. The caissons, when floated out, weighed about 2,430 tons each, and their draught would be about 25 ft. They were sunk in about 46 ft. of water, and their tops, when sunk, were about 3 ft. above mean sea-level.

On the Amsterdam Ship Canal the new lock to be constructed at Ymuiden is to be 1,110 ft. long and 165 ft. wide, with 49½ ft. over the sill, and it is proposed to build the lock heads, gate recesses, and gates in a shallow excavation, and when sufficiently advanced to tow the structure out and sink it in position, the site having previously been prepared by dredging. The lock walls are to be similarly constructed as reinforced-concrete caissons and floated into position.

THE BEST WAY OF PROTECTING REINFORCED CONCRETE FROM MARINE DETERIORATION.

By FRANCIS ERNEST WENTWORTH-SHEILDS, O.B.E., M.Inst.C.E.

OUR experience of reinforced concrete for maritime structures now extends over twenty years. During this period, we have learnt that this material is likely to be very useful to the harbour engineer. But there have been several failures, and we find that reinforced concrete is much more liable to deterioration in and near sea-water than elsewhere. It is of the greatest importance to study the causes of such deterioration and how it may be avoided.

Nature of Deterioration.—Failures in marine structures have been of four kinds: (1) The concrete has become softened owing to the chemical action of sea-water on the Portland cement which it contains. (2) The concrete has scaled off owing to the action of frost. (3) The concrete has worn off owing to attrition by travelling shingle and stones. (4) The concrete has split and cracked owing to the rusting of the enclosed steel and its consequent increase in volume.

The first three classes of failures are, of course, not limited to reinforced concrete; they are comparatively rare, the fourth being the most common type of failure.

Preventive Measures;—(1) The subject of the softening action of sea-water on Portland cement concrete has frequently been discussed in this Institution and elsewhere, and the various means for its prevention are well known. Generally, it has been found that cement concrete of good quality can safely be used in salt water, provided that it is made highly impermeable. The precautions needed to produce impermeability will be referred to later.

(2) The scaling of concrete by frost is a serious matter in very cold climates. To prevent it, the concrete should be allowed to harden in air before being exposed to tidal action, and again it should be strong and impermeable.

(3) Where concrete is liable to be worn away by moving stones, it has been found advisable to use a tough aggregate with large stones, to make the concrete strong, and to let it harden in air before it is exposed in position. Even in these cases it is probable that impermeability is an important quality.

(4) Generally speaking, it has been found that the steel in reinforced concrete is well protected from rust provided that the concrete is of good quality. In maritime structures, however, there have been several cases where moisture and air have penetrated through good concrete to the steel, causing the latter to rust and swell, and to crack or burst off the concrete covering. Many precautions have been suggested to prevent this action. Some have advocated coating the steel rods with paint. Probably a better coating is neat P.C. grout, as this does not decrease the bond strength; but it is liable to come off unless the rods are very carefully handled. It is important that overcrowding of steel should be avoided and the use of flat steel stirrups or links, which cause voids in the concrete, and which prevent it from properly surrounding the main bars, should be forbidden. The size of stones should be limited to, say, ¾ in. The thickness of the concrete cover is a matter of importance. In the early days a cover of 1 in. to 1½ in. was considered sufficient, but there is now a tendency to increase it to 2 in. or 2½ in. Working stresses should be kept low, and the structure as a whole should be stiff, especially where heavy live loads have to be supported. Care should be taken to prevent stray electric currents passing through the structure. But it would seem that the most important preventive is to make the concrete impermeable.

Permeability of Concrete.—Probably the most effective way of preventing all kinds of deterioration is to make the concrete highly impermeable. To effect this many means have been suggested, but their relative importance is uncertain, and the matter requires further investigation. The concrete should be well mixed. Both stones and sand should be well graded, *i.e.*, they should not be uniform in size, but varying from coarse to fine. Mr. Fuller's investigations in this subject are well worth studying.* Another important matter is the proportion of water used in mixing, which should be neither too great nor too small, as either excess tends to produce a porous concrete. It has been suggested that denser concretes can be made by the use of special cements, but the writer has seen no experiments which are conclusive on this point. Again, many substances are on the market for which it is claimed that if mixed with concrete or mortar, they greatly decrease its permeability. An elaborate investigation into a number of such substances was made by the American Bureau of Standards in 1911.* They rather tend to show that the additon of such substances was of little use in the case of rich mixtures, and that some of them decreased the strength of the concrete. Probably the best pore-filler is Portland cement itself. In other words, for maritime structures a rich mixture should be used. Proportions of 1 cement to 3½ aggregate are now commonly used, and a mixture of 1 : 1 : 2 has been recommended. Such a mixture may seem to be extravagant, but after all, the cost of the extra cement is but a small proportion of the whole cost, and the money is probably well spent. Another means of preservation is the coating of the outside of the concrete with some kind of impervious liquid. Experience has shown that fuel oil, which has been spilt on to the water and deposited on reinforced concrete, has proved to be an effective preservative. It has been found that paraffin wax, bituminous paint, tar, and various kinds of linseed-oil paint, are more or less effective in preventing water from entering into the pores of concrete. It has also been found that such paints, to be lasting, must not be applied until the concrete has matured for some months. Further investigation is needed to ascertain which of them is likely to have the longest life. An interesting letter appeared recently in the *Engineering News-Record*,† in which it was stated that French engineers now followed the lead of M. Voisin, of the Department of Ponts et Chaussées, who advocated the following treatment for structures in sea-water: Concrete 1 : 1½ : 2½, to be covered with a thin coating of neat cement paste, and over this two coats of boiling coal-tar. It was further stated that after ten years' experience this method of construction had proved quite satisfactory.

Tests for Permeability.—We are badly in need of a simple test for permeability. Of course, no concrete is absolutely impermeable, but it should be possible without elaborate apparatus and within a short period to ascertain whether a concrete conforms to a certain standard of impermeability, just as we test a Portland cement for strength or soundness. Concretes have been tested by moulding them into slabs and forcing water through the slabs under pressure, and measuring the water passed in a given time. Another method of testing is to make small cubes of concrete, stove-dry them, and then soak them and observe how much water they absorb. A test for waterproof coatings which was used by the American Bureau of Standards,‡ consisted of making small discs of cement mortar coated on the under surface and around the sides with the material to be investigated. The disc was then placed in a shallow tray containing water, which, if the coating was not damp-proof, crept up through the mortar to the top, where it revealed its presence by colouring a paper which was pasted on to the disc and moistened with a solution of phenolphthalein in alcohol. Mr. Nathan Johnson of New York has examined concretes for porosity by means of the microscope.§ Further experiments are needed to determine the most simple and reliable test, and a standard of excellence needs to be laid down.

REASONS FOR THE DETERIORATION OF REINFORCED-CONCRETE STRUCTURES ABOVE MEAN TIDE LEVEL.

By LEOPOLD HALLIDAY SAVILE, M.Inst.C.E.

SINCE the introduction of reinforced concrete in the construction of piers, wharfs, &c., the design generally adopted has been more or less on the lines of similar structures in timber, and it was until lately generally believed that these structures, apart from accidents, would be of a permanent nature. It has, however, been forcibly brought to our notice in structures of this sort built by the Admiralty, and I understand in those at other places at home and abroad, that in many cases serious defects have been noticed in portions of the structures situated above mean tide level. The first indication of trouble is usually shown by a line of rust coloration on the surface running parallel and from 1 in. to 2 in. from the corners: these lines of colour gradually develop into cracks which enlarge until a corner comes away, leaving the main reinforcement bar bare. This not only happens to the upper portion of the piles and the diagonal and horizontal bracing, but also to the deck beams which are well above high water level.

It would be of great interest and value if those members who are responsible for the maintenance of this kind of structure would give their experience as to whether they have had defects of this nature to deal with, and if so, how they account for them, in view of the fact that these defects do not appear to occur below mean tide level, or if so, only to a very limited extent. It would also be of interest to discuss means of preventing similar defects in future structures, and also any useful means that could be adopted for treating those existing. If it is impossible to adopt satisfactory means of preventing these defects in structures designed on the present generally accepted lines, the question of adopting a different form for, at any rate, that portion above mean tide level will have to be considered.

It is understood that the conditions necessary for the formation of rust are a supply of oxygen and water, and especially water in the form of vapour. On this basis the following theories are presented:—

1. At a certain level below high water, depending on the size of pile and range of tide, the concrete would be continuously saturated with water and any small volume

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* This and the succeeding notes to page 71 were read at the meeting at the Institution of Civil Engineers on Wednesday, June 29, 1921.

* See "Concrete Plain and Reinforced," by Taylor and Thompson (Chapman and Hall).

* See "Technologic Papers of the Bureau of Standards" No. 3 (Government Printing Office, Washington).

† *Engineering News-Record*, March 31, 1921.

‡ "Technologic Papers of the Bureau of Standards," No. 3.

§ See *Concrete and Constructional Engineering*, June-December, 1915.

of oxygen dissolved in it, when once consumed by oxidation, would be difficult to replace, as it may be assumed that the water below the level of saturation remains continuously in the same region of concrete. Moreover, the water would probably become very slightly alkaline. This would then account for the non-appearance of rust below the line of saturation.

2. Above the line of saturation there would generally be a certain amount of moisture in the pores of the concrete. This would be partly in the form of liquid and partly in the form of vapour. As the temperature rises the liquid in the pores would tend to vaporise. At night, when the temperature fell, some of this vapour would condense, and in condensing a supply of air would be drawn in, giving the necessary oxygen for rust formation. If the pores in a circular pile are uniformly distributed and the daily range of temperature is 40 deg. F., the amplitude of the movement of every particle of air throughout the pile during the 24 hours would be about one-twenty-fifth of its distance from the centre, assuming that the air can expand. If the air is damp this movement would be increased in proportion to the vapour condensed.

3. A theory which would account for rusting at high water level could be constructed as follows:—Steel is a good conductor of heat, concrete is a poor one. The temperature of the steel reinforcement near the water-line would correspond with the temperature of the sea, the heat being easily conducted up from the points. The temperature of the concrete above high water would correspond with the atmospheric temperature. At night when the air temperature falls the outer skin of concrete would contract but the steel would remain, for some distance above the water-line, at or near the temperature of the sea. This would tend to put the concrete above sea level in tension, and the steel in unusual compression, and might at least in the long run destroy the bond of the steel and concrete, if not actually producing hair cracks in the concrete which would admit the necessary oxygen.

4. When a load passes over a reinforced beam it is usual to assume that the steel takes all the tension. In any case, whether this is so or not, if the steel takes the greater portion of the tension it will extend and its cross section will diminish, and this would tend to produce a vacuum which would draw in air. It is suggested that in this way after repeated application of loading, such as happens when railway trucks pass over beams, the bond of the steel and concrete is broken and air may be drawn in.

5. Experiments have been carried out (Sir Francis Galton, "Hospital Construction," pp. 56–57) to show that in a porous solid, such as an ordinary brick wall, where a temperature gradient exists, gases will flow through the pores from the side at high temperature, and escape on the side at low temperature. Whether the experiments quoted are reliable as to the quantity of gases passing is not known, but information on this point is very desirable, as if true, this would indicate the necessity of making impervious decks of reinforced-concrete jetties, which are exposed on the top to the sun.

6. Information might be obtained from inspection of reinforced-concrete beams, lintels, &c., carrying stationary loads, whether erected on the coast or inland, and a comparison of these with structures subjected to moving loads and of the same age could scarcely fail to be of use.

7. Electrolysis may also be an active agent in producing deterioration, and information as to this would be of value. Since writing the above, Technologic Paper, No. 52, Bureau of Standards, Washington, U.S.A., has come to hand, dealing with electrolysis.

SECTION III.—MACHINERY.

Exhaust Steam; Its Employment for Power, Heating, &c.

By Ernest Richard Dolby, M.Inst.C.E.

The expression "exhaust steam" may, for the purpose of this note, be defined as "Steam which has passed through a prime mover." No limitation of pressure is suggested, as it may vary from that of the atmosphere to 60 lb. per square inch or even higher. The deciding factor will naturally be the specific purpose for which it is to be employed.

Before considering the means which may be adopted for utilising some of the heat now lost, it should be remembered that in non-condensing engines about 90 per cent. of the heat which is contained in the steam entering the engine is discharged with the exhaust; also that in the condensing engine or turbine, about 60 per cent. of the total heat in the fuel burned passes to waste with the cooling-water effluent from the condenser. The total heat units from water at 32 deg. F. in a pound of dry saturated steam at 150 lb. gauge pressure are about 1,194, while in exhaust steam at 1 lb. gauge pressure they are about 1,147. Exhaust steam may be employed for the generation of power, or electric energy, or for heating, drying, cooking, and so forth. The problem before us is the better utilisation of the heat in the steam. This subject comes before the engineer not as a theoretical problem, but as a practical question relating to a given factory, mine, public institution, or business premises. If in a given case there is a constant demand for power, and at the same time a demand for heat which may be exactly supplied by the utilisation of the heat ejected by the prime mover, then the solution of the problem is simple. In practice this ideal condition is rarely met, and probably never subsists for the entire year.

In the opinion of the author, the most efficient utilisation of the thermal value in coal cannot be obtained until there are sets of public mains provided by the community for public utility. One set of the mains might receive electric energy in the form of alternating current at a standard pressure and frequency; another set might receive steam at a pressure of 5 lb. to 10 lb. per square inch; while a third set would deliver water at a temperature of 180 deg. to 200 deg. F. The electric energy, steam, and hot water, would be by-products from scattered installations comprising prime movers driven by steam.

The subsidiary electric mains would be coupled to the existing public supply mains, as is now the case on the north-east coast of England, the consumer being paid for what he delivers and charged for what he consumes. The steam mains would furnish direct heating in radiators, drying-chambers, and calorifiers for the supply of domestic hot water, and wherever practicable the condensate would be drawn back by an air-pump to the starting point. Such mains are common in the United States, although rare in Great Britain, where, however, several large blocks of buildings in Manchester are supplied with exhaust steam from an electric generating station. The hot-water mains would convey water heated in exhaust steam calorifiers and circulated by pumps. In some instances, owing to the configuration of the ground, and the height of buildings, steam mains would be preferable, while in other cases hot-water mains would be better.

The subject may be divided under the following headings:

Class I.—Power Only Required.—(1) If steam be employed solely for power purposes with a fairly steady load, and condensing engines are used, then the saving of the thermal loss in the condensing water may be obviated by eliminating the condenser, providing steam at a somewhat higher pressure, and discharging the exhaust at, say, 5 lb. back pressure into a public steam main. Electric power from the public mains might in some cases be substituted with advantage.

(2) If the load is intermittent, such as that of colliery winding, hauling, &c., then the engines are usually of the simple type and exhaust to the atmosphere direct. If more power be required, then the exhaust may be passed first into an accumulator, of one of the well-known types, and thence into an exhaust steam turbine. If extra power is not required, then this turbine can be used to drive an alternator and the current delivered to the public electricity mains. The heat loss in the condensing water would still continue, but this could be obviated by omitting the turbine and discharging from the accumulator to the public steam mains.

Class II.—Power and Other Uses.—(1) If the other uses require steam at about atmospheric pressure only, then steam engines or steam turbines may be used for power only, or for electric energy also; they would be non-condensing, and the exhaust at a back pressure not exceeding 1 lb. would be taken into the private heating mains, and an air pump used on the return. Steam at this temperature would not boil water, but it could be used for drying, air heating, water heating, and in radiators.

(2) If rapid boiling or high-temperature heating be necessary, as is quite general in paper-mills, chemical works, &c., then the stop-valve pressure would be selected so that the necessary power could be obtained from the prime mover within the assumed fall of pressure. With steam turbines several different "pass-out" pressures may be selected, say, 60 lb. for cooking the raw product, and 15 lb. to 30 lb. for heating the drying cylinders. If reciprocating engines were used they would be of the simple type exhausting at the highest back pressure desired.

The methods of allocating charges to the various purposes for which the heat is employed are often fallacious. The author is of opinion that the thermal units employed for each service should be charged to that service, and that all costs of labour, fuel, stores, taxation, interest, and sinking fund should be charged *pro rata* on the thermal units consumed by each service. Information has been most kindly supplied to the author by several firms; it has been impossible to incorporate details within the prescribed limits of this note, but the author hopes that these may be put forward in the discussion. The data prove that enormous savings can be effected by using back-pressure on reciprocating engines employing "pass-out" steam turbines, and utilising apparatus to employ the heat in the exhaust steam. The cost of electric energy can in many cases be reduced well below the rates charged by public authorities. It must, however, be borne in mind, that many private electrical generating plants in works, and also in public institutions, have been removed, even although the whole of the exhaust steam was usefully employed. This has occurred particularly in London, but the author believes that in most of these cases the high cost of labour, the necessity for three shifts of stokers, and the high costs of secondary battery maintenance have been the deciding factors in the removal.

Comparison between Reciprocating Pumping Engines and Turbo-driven Centrifugal Pumps.

By Hugh Lupton.

The matter which I am now bringing forward for consideration is the relative merit for waterworks pumping of the triple expansion reciprocating pumping engine and the steam turbine-driven centrifugal pump. Pumping from wells and boreholes cannot be conveniently done by the latter method. I therefore confine myself to the consideration of cases in which water is within suction distance of the pump, and, with regard to size, to horse-powers measured in water lifted from approximately 150 to 600.

The principal points which the waterworks engineer considers in the selection of plant are, I take it, the following, arranged in order of importance: (1) Reliability. (2) Running costs, which include fuel consumption and, therefore, thermal and mechanical efficiency in actual work. (3) Capital cost.

Taking these points in order:—

1. *Reliability.*—It is natural to expect that the reciprocating engine would in this respect have the advantage. The usual speed of a reciprocating pumping engine working plunger pumps is from 30 r.p.m. to 40 r.p.m., or, say, a piston speed from 180 ft. to 280 ft. a minute, while in so much as the blade speed of a steam turbine, if it is to work efficiently, must bear a ratio to that of the impinging steam, the number of revolutions per minute is necessarily large. It will be found, I think, that the lowest number of revolutions of the steam portion of the plant will not be less than 3,000 per minute, while speeds up to or over 10,000 are in common use. Obviously, with speeds of this character, a very trivial accident might easily cause a most serious breakdown. The turbine pump, the peripheral speed of which in feet per second approximates to eight times the square root of the head in feet pumped against per stage, also runs at a comparatively high velocity, though considerably less than that of the steam end of the plant, necessitating the use of reduction gear between the two. It would therefore be expected that a reciprocating engine would have the advantage in durability, and this seems to be borne out by experience.

The durability of the reciprocating pumping engine is well known and hardly needs exemplifying, but I may just mention that a triple vertical supplied to the Bristol Waterworks in 1914, and which has been at work constantly since that date, having pumped 7,600,000,000 gallons against a head of 210 ft., used on its initial trial, made in 1914, 12·37 lb. of steam per P.H.P. hour ascertained from pump displacement, and when again tested in January of this year, was found to be using 12·6 lb. of steam, or practically the same amount. In this connection I may mention that the total repairs since this engine was started, apart from letting up the bushes, &c., done by the engine-room staff, have cost 50*l.* 12*s.* 6*d.*

Experience in the case of turbine pumping is, of course, much more limited, but steam turbines have been in use for a number of years for the generation of electricity, and I do not suppose there is a station engineer who has not experienced, and that not once but several times, a complete breakdown of one or more units. I myself remember a case in which, owing to the breaking of the spindle of the oil circulating pump, a turbine of about 10,000 h.p. was out of commission for several months.

2. *Running Costs.*—Of this much the most important factor is coal, and in this respect the reciprocating engine again has the advantage. The pump plungers being directly coupled to the steam piston rods without the intervention of any gearing, the mechanical efficiency, that is, the horse-power measured in pump displacement, as compared with the indicated horse-power of the engine, is extremely high, upwards of 90 per cent. A reference to the attached schedule of steam consumptions, shows that within the limits specified, these vary from 13 lb. to 11 lb. per actual P.H.P. hour in water lifted. And these figures are inclusive of air and feed pumps, *i.e.*, they represent the whole consumption of the plant.

The examples quoted in this schedule are all cases taken from actual practice. Most of the engines referred to were built by Messrs. Hathorn, Davey and Co., Limited, but the results are similar to those published from time to time of engines made by other makers, and two of these are inserted for the purpose of comparison. In arriving at these figures 2½ per cent. has been added for slip. The reciprocating engine also returns a considerable amount of heat to the boiler from its jacket and receiver drains, which is not the case with a steam turbine. And it will be noted that the thermal efficiencies given in the schedule which have been calculated on the water horse-powers are uniformly high.

The figures of coal consumption have been calculated on the basis of an efficiency of 65 per cent. for the steam-raising portion of the plant, 20 per cent. has been added for general losses, and a further 10 per cent. for deterioration, so that the figures are, I believe, approximately reliable for actual waterworks practice. Coal of a calorific value of 13,000 B.Th.U. per lb., has been taken at a cost of 40*s.* per ton, and based on these figures the actual cost of a horse-power for a year of 300 twelve-hour days, and correspondingly for one of 300 twenty-hour days, has been calculated and is given in the schedule.

In respect to coal consumption, the turbine-driven pump is considerably less efficient. In the first place, the pump itself, when accurately made, in first-rate order and running under the exact conditions of head for which it was designed, has an efficiency of not more than 75 per cent. to 80 per cent., reduction gearing of say 94 per cent. to 96 per cent., while the hourly B.H.P. consumption of a steam turbine of sizes within the limits named, and of first-rate construction such as would be suitable for high-class waterworks plant, varies from about 10·5 lb. to 15 lb., giving an over all consumption per actual horse-power in water lifted of from, say, 14·5 lb. to 20·5 lb. It should also be remembered that while the efficiency of a reciprocating engine is nearly constant over a very large range, both of speed and head, that of the turbo centrifugal plant falls heavily, if, as is frequently necessary at waterworks, the conditions of work are modified. There is not as yet, so far as I am aware, the same prolonged experience of the working of turbine-driven centrifugal pumps as is available in the case of the reciprocating type, but by the kindness of Messrs. Greenwood and Batley, the British Thomson Houston Company, Mr. McPherson, of the Bristol Waterworks, and Mr. Durham, of the Metropolitan Water Board, I have prepared a schedule on the same lines as that of

COMPARISON BETWEEN RECIPROCATING PUMPING ENGINES AND TURBO-DRIVEN CENTRIFUGAL PUMPS.

TABLE I.—TRIPLE-EXPANSION PUMPING ENGINES. CONSUMPTIONS AND COSTS.

	Name.	Size.	Speed, R.P.M.	I.H.P.	W.H.P.	Mechanical Efficiency.	Steam Pressure by Gauge.	Temperature.	Superheat.	Lb. Steam Used per Pump Displacement, H.P. Hour.	Lb. Steam Used per W.H.P. Hour allowing 2½ per Cent. Slip.	Thermal Efficiency W.H.P. Compared with Heat Expended.	Vacuum.	Barometer.	Coal per W.H.P. Hour taking Boiler Efficiency at 65 per Cent. Coal of 13,000 B.T.U. per lb., Allowing 20 per Cent. for General Station Losses and 10 per Cent. for Deterioration.	Coal Cost per W.H.P. Year of 900 12-Hour Working Days with Coal at 40s. per Ton.	Coal Cost per W.H.P. Year of 300 20-Hour Working Days with Coal at 40s. per Ton.	Capital Cost, being Interest and Sinking Fund for each W.H.P. Installed and per Year on a 25 Years' Life Calculated on Money at 6 per Cent.	Total Coal, Interest, and Sinking Fund Cost per W.H.P. Year of 900 12-Hour Days.	Total Coal, Interest, and Sinking Fund Cost per W.H.P. Year of 300 20-Hour Days.
		in. ft. in.				per cent.	lb. per sq. in.	deg. F.	deg. F.			per cent.	in.	in.	lb.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.
1	Leeds City	Cylinders. 15–25–40 Rams. (3) 13½ × 3 0	34·64	183·7	167·6	91·3	138	359	None	13·05	13·4	16·9	27·79	—	2·34	7 10 0	12 11 0	4 14 0	12 4 0	17 5 0
2	Bristol* ..	Cylinders. 16–28–46 Rams. (3) 18 × 3 0	27·5	184·6	167·9	91·0	160	370	None	12·28	12·58	17·96	—	—	2·21	7 2 0	11 16 0	5 12 0	12 14 0	17 8 0
3	Rosario ..	Cylinders. 15–25–40 Rams. (3) 16 × 3 0	36·0	232·0	209·0	90·0	177	431	53	12·28	12·6	17·4	28·0	29·7	2·26	7 5 0	12 2 0	4 2 0	11 7 0	16 4 0
4	Margate†	Cylinders. 20–36–53 Rams. (3) 15½ × 4 0	23·3	264·0	242·0	91·0	160	393	22	11·64	12·0	18·6	—	—	2·13	6 17 0	11 8 0	—	—	—
5	Lincoln† ..	Cylinders. 26–45–68 Rams. (3) 16½ × 4 0	20·0	385·0	345·0	90·0	170	535	160	10·97	11·2	18·7	—	—	2·12	6 16 0	11 7 0	—	—	—
6	Odessa ..	Cylinders. 20–36–54 Rams. (3) 17 × 3 6	38·0	417·0	380·0	91·0	180	385	5	12·47	12·8	17·6	27·75	—	2·25	7 5 0	12 0 0	3 14 0	10 19 0	15 14 0
7	Rand Water Board	Cylinders. 23–43–64 Rams. (3) 12 × 3 0	37·5	502·0	461·0	91·8	182	500	120	11·0	11·33	18·8	22·67	25·24	2·11	6 16 0	11 6 0	3 8 0	10 4 0	14 14 0
8	Milwaukee	Cylinders. 28–48–74 Rams. (3) 32 × 5 0	20·0	574·0	520·0	90·6	125	353	None	12·98	13·3	17·0	27·0	—	2·31	7 8 0	12 8 0	—	—	—

* The capital cost per horse-power in this case is somewhat high, as the engine is rated at a higher speed than was in use at the time of this test.
† This engine also had bucket pumps, but for the purpose of these figures the whole load has been taken as if it had been on the ram pumps.

TABLE II.—STEAM TURBINE-DRIVEN CENTRIFUGAL PUMPS. CONSUMPTIONS AND COSTS.

	Name.	Size.	Speed, R.P.M.	W.H.P.	Steam Pressure by Gauge.	Temperature.	Superheat.	Lb. of Steam per W.H.P. Hour.	Thermal Efficiency W.H.P. Compared with Heat Expended.	Vacuum.	Barometer.	Coal per W.H.P. Hour taking Boiler Efficiency at 65 per Cent.; Coal 13,000 B.T.U.; Further allowing 20 per Cent. for General Station Losses and 15 per Cent. for Deterioration.	Coal Cost per W.H.P. Year of 900 12-Hour Working Days with Coal at 40s. per Ton.	Coal Cost per W.H.P. Year of 300 20-Hour Working Days with Coal at 40s. per Ton.	Interest and Sinking Fund for Each W.H.P. Installed and per Year on a Life of 15 Years, Calculated on Money at 6 per Cent.	Total Coal, Interest and Sinking Fund Cost per W.H.P. Year of 900 12-Hour Days.	Total Coal, Interest and Sinking Fund Cost per W.H.P. Year of 300 20-Hour Days.
					lb. per sq. in.	deg. F.	deg. F.		per cent.	in.	in.	lb.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.
1	Estimate	—	4,500/800	144	180·0	480	100	19·3	10·8	28·50	30·0	3·84	12 6 0	20 12 0	3 16 0	16 2 0	24 8 0
2	Bristol Trial—De Laval	14 in. Pump	10,500/750	260	149·4	366	None	20·34	10·82	27·85	30·05	3·814	12 4 0	20 6 9	1 13 4	13 17 4	22 0 0
3	Ferry Lane Trial—De Laval	—	10,500/748	276	150·0	459	93	18·38	11·62	28·0	29·5	3·56	11 8 0	19 0 0	—	—	—
4	Estimate	—	4,500/800	288	180·0	480	100	17·64	11·9	28·50	30·0	3·5	11 4 0	18 16 0	2 6 4	13 10 4	21 2 4
5	Estimate	—	4,500/700	432	180·0	480	100	17·1	12·2	28·50	30·0	3·39	10 17 4	18 3 0	1 18 0	12 15 4	20 1 0
6	Battersea. Trial—Parsons-Gwynne	—	6,000/1,500	470	195·0	556	170	16·7	12·16	28·0	—	3·4	10 18 0	18 4 0	—	—	—
7	Estimate	—	5,000/700	576	180·0	480	100	14·5	13·8	28·50	30·0	2·9	9 6 4	15 10 8	1 12 0	10 18 4	16 12 8

the reciprocating engine, and which, always provided that the load is that for which the pump was designed, will, I believe, be found substantially accurate. It will be seen that the coal cost of a horse-power on the same basis of boiler efficiency as before, for a 300 twelve-hour day year, would be from 9*l.* 6*s.* to 12*l.* 6*s.*, as against 6*l.* 10*s.* to 7*l.* 10*s.*, with a reciprocating engine, and for a 300 twenty-hour day year, 15*l.* 10*s.* to 20*l.* 10*s.* as against 11*l.* 6*s.* to 12*l.* 11*s.* with the reciprocating type.

3. *Capital Cost.*—When, however, we come to the immediate capital cost, the turbine plant gains considerably, although in considering this point allowance must be made for the proved great durability of the reciprocating engine. It may be considered that present-day costs are likely to fall somewhat, and for the purpose of comparison I have taken prices as at the year 1918, and given in the schedule the annual cost per water horse-power installed. Interest is taken at 6 per cent. In the case of the reciprocating engine, I have allowed twenty-five years life for the plant, and in the case of the turbine pump fifteen years, and have given in the schedule the estimated combined fuel and capital cost for each type of plant. The capital costs are in each case for the engine, pump and condensing plant only, and do not include pipes and valves, floor plates, &c., which would be approximately the same whatever type of plant is adopted.

The figures given of efficiency, steam and coal consumption are, I believe, very nearly reliable, certainly for the reciprocating engine and also for the turbine where constant conditions of work approximating to those for which the plant was designed can be guaranteed.

The figures of capital cost are, owing to differences of conditions at different stations, and also to price fluctuations, much more debatable, and I only put them forward after considerable hesitation as a general indication. For permanent work, and where an all-the-year-round load is anticipated, the triple reciprocating engine with direct-coupled ram pumps is the most advantageous proposition, but for standby plant the turbine-driven pump has the advantage.

SECTION IV.—MINING AND METALLURGICAL PROCESSES.

THE EMPLOYMENT OF WATER POWER IN THE DEVELOPMENT OF THE MINERAL INDUSTRY.

By JOHN WILLIAM EVANS, F.R.S.

THE utilisation of water-power in mining and ore-dressing is almost, if not quite, as old as mining itself. The separation of light from heavy material or of material of different sizes by means of water in motion is a commonplace; but running or falling water has also been extensively used as a motive power in mining operations, in winding and pumping, in the operation of stamps, and in many other ways, either directly or through the intervention of electricity, which enables the power to be transmitted a considerable distance, or by means of compressed air which is especially suitable when the volume of the flow is considerable and the fall small. The energy of the Sivasamudra Falls has been utilised in the Kolar Gold Field, and it is proposed to make use in the same way of that of the Victoria Falls on the Rand. The electric energy generated by water-power has also been widely utilised in electrolysis for the production of almost chemically pure copper, zinc and nickel, and above all in the production of metallic aluminium. The electrical reduction of iron is also making way. During the war there was a remarkable advance in Sweden, where the number of electric furnaces employed in this industry increased from 8 in 1914 to 25 in 1917 and 28 in 1918, and the output of pig-iron obtained from them increased from 5,786 tons in 1911 to 75,684 tons in 1918. The day is at hand—indeed, a commencement has already been made—when electrolytic methods will enable metals to be extracted with commercial success from ores which are too poor to be dealt with by smelting operations. On the other hand, the manufacture of substitutes for mineral substances such as synthetic nitrates, artificial graphite and carborundum by electric energy will tend to some extent to oppose the development of the mineral industry. There is, however, reason to believe that the increase in the use of electricity obtained from water-power will have far greater effects in facilitating both mining and metallurgical operations. Attention has been recently directed to the possibility of utilising the tidal forces of the Severn. If this is ever successfully accomplished, the metallurgical history of South Wales will tend more and more to be developed on electrical lines. Whether the still vaster tidal forces of the Channel and the Pentland Firth will ever be employed in the service of man is a problem that only future generations can decide.

The problem of utilising the water power of the mountain areas of the United Kingdom is complicated by the objections which are very properly urged against interference with the scenic beauty of the areas where water-power is available. This is an obstacle which it is the duty of our engineers to overcome. A great engineer should be an artist as well as a mechanician, and should be able to obtain the material results at which he aims with due regard to esthetic considerations. It should be possible not merely to refrain from injuring the beauty of such a mountain area, but even to accomplish the task of increasing it. This is a problem which the designers of the great aqueducts of antiquity were not wholly unsuccessful in solving. The question is somewhat urgent because we can only secure the output of aluminium in this country which national considerations demand, if there is a considerably greater utilisation of water-power than has been hitherto permitted.

There are few mountainous districts that do not contain vast reserves of water power, but some of the greatest, including the Alps and the Himalayas, are not correspondingly wealthy in mineral resources. The water-power of the Alps is, however, now being employed in the extraction of aluminium from bauxite; this was formerly largely imported from France, but is now obtained mainly from the Carpathians and Dalmatia. In the long line of Sierras that rise from the eastern shores of the Pacific from Alaska to Tierra del Fuego, the water-power and mineral deposits are frequently associated, and the resulting economic advantages will increase rapidly as metallurgical science advances.

Water-power is, however, also largely developed where the drainage of the great plateaux descends to the plains. The Victoria and Sivasamudra Falls already referred to are examples, but there are many other powerful streams both in East and West Africa and in India that may be exploited. In addition to Niagara there are in Canada numerous falls in the great drainage basins of the St. Lawrence and of James Bay which provide a total of some 8,000,000 h.p., and in the development of the mineral wealth of the wide pre-Cambrian shield—of which Sudbury, Cobalt and Porcupine represent in all probability only a fraction, and which bids fair to rival that of the Rockies—water-power should play a conspicuous part. Already its use in the mining and metallurgy of Canada has had a marked effect in stimulating production.

Turning to South America, we find in British Guiana valuable sources of energy in the rivers that descend from the southern highlands. A preliminary estimate has been made that the falls of the Cuyuni, the Essequibo and the Demerara alone develop a minimum of nearly 800,000 h.p. in the dry season. After making liberal deductions for loss of power in conversion into electrical current and transmission there is at least 440,000 h.p. available for commercial purposes—and this does not include the immense amount of water-power available in the falls of the Courantyne, that forms the boundary with Dutch Guiana, and in those of other streams, which have not been included in these calculations.

These reserves of water-power in our tropical Colonies and Protectorates are of especial interest in connection with the occurrence of bauxite, hydrate of aluminium, the most readily available source of aluminium. This is most characteristically developed in the tropics, where it appears to be formed under certain conditions by the action of a warm, moist climate on alumina-bearing rocks. Where, on the other hand, it is found in temperate regions, it probably dates from former periods when tropical conditions prevailed.

Extensive deposits have been recognised in British Guiana, the Gold Coast and India, in each case within a reasonable distance of water-power, while it is only in the last-mentioned that coal is available, and then only in the neighbourhood of some of the deposits. One of the most important results of the economic production of aluminium will be the facilitation of the transmission of power by the substitution of aluminium for copper in long-distance conductors. For the former must ultimately be available at lower prices, having in view the comparatively restricted occurrence of the latter.

There are, generally speaking, three different courses that may be taken in developing deposits of bauxite. In the first place the material may be exported after only a preliminary mechanical dressing, where that is possible. The chief obstacle in the way is the high cost of freights at present prevailing, but the 20 per cent. *ad valorem* tax now placed on exports from France, hitherto the chief source of the ore, to some extent diminishes these drawbacks.

The second course would be to refine the bauxite on the spot, removing impurities and water so as to obtain pure aluminium oxide. This would effect a considerable saving of freight, but up to the present it has not been carried out locally on account of the absence of coal. By the help of electric energy, however, it can probably be made a commercial success, if the power can be provided sufficiently cheaply and the costs of plant and labour are not too high. The possibility of obtaining a market for by-products of the operation might also be an important consideration.

Finally the matter might be carried a step farther and the water-power employed also for the extraction of metallic aluminium. This will undoubtedly be done in India, which has an almost unlimited market for the metal in its own territories and neighbouring countries. In the case of British Guiana, too, there are important markets at no great distance in South and Central America and the West Indies. The question of labour is, however, exceptionally difficult.

The problem of the utilisation of water-power in the tropics is complicated by the irregularity of the rainfall. In the absence of some form of storage in natural and artificial reservoirs this causes a similar irregularity of the river flow and of the horse-power available. Figures have been given above for British Guiana showing the horse-power available in the dry season. When the river is in flood it may be three or four times as much. It would be difficult to reap the full benefit of this increase because the problem of utilising the power of such a stream becomes entirely transformed when its waters have risen to a much higher level.

It is also most important for the economic development of metallurgical work that the power available should be more or less uniform throughout the year. The problem of the storage of mechanical power on commercial lines is probably not insoluble from the engineering standpoint. One can conceive the employment of the excess power when the river is in flood in the elevation of rock masses weighing millions of tons by hydraulic presses and the subsequent reconversion of the potential energy thus accumulated into kinetic and electric energy; but the more obvious procedure, and that usually adopted is to store as much as possible of the excess of precipitation in the rainy season in artificial reservoirs. In few of the areas considered do there appear to be very serious topographical difficulties in effecting this, but the expense would be considerable, and it has to be considered how far this would militate against economic success.

There is, moreover, another difficulty, the excessive evaporation in the tropics. Colonel Lyons has shown that only a small fraction of the rainfall in the drainage areas of the Victoria and Albert Nyanza reaches the lower Nile, and all who, like the writer, are familiar with the numerous storage reservoirs of the Peninsula of India, know what a large proportion of the water is lost by evaporation—some 6 ft. or 7 ft. per annum, it is believed, over the whole surface. The prevention of this loss is a matter of urgent importance, and it could, I think, be best effected by the construction of some form of cover floating on the surface of the water. A film of oil would probably serve the purpose, but only temporarily, as it would itself evaporate.

The subject of the utilisation of water-power in the development of mining industries is a vast one, and all I have attempted to do here is to direct the attention of engineers to the interest and importance of the problems it presents, which it is their task to solve.

RECENT DEVELOPMENTS IN COAL-CLEANING PROCESSES.

By ROBERT NELSON.

The stress of war and the resulting period of Government control have had, amongst many important results, a definite and adverse effect on the quality of the product of the coal industry. That coals of all kinds have deteriorated in respect of the amount of incombustible material to be found in them will be denied by few suppliers and by no users. The small or slack coals commonly used for industrial purposes are, as one would expect, the worst offenders. "Unscreened small" is the class of coal generally used by the large electricity works throughout the country, and from forty separate records where a comparison of the ash in pre-war and post-war coal (purporting to be the same class of coal from the same source) can be directly made, the average increase in the quantity of ash is nearly 63 per cent. That is to say, coal which formerly contained 8 per cent. of ash now contains on the average 13 per cent. and coal which formerly contained 12 per cent. or 13 per cent., now contains on the average more than 20 per cent.

There is no reason to suspect that electricity works are being specially victimised. They are, in fact, amongst the comparatively few works that can claim to give some approach to adequate attention to the selection and economical use of fuel. To few industrial concerns of any kind, and, with one exception, to none of the same magnitude is the quality of its fuel of such enormous importance.

Recent experience having made the problem of how to secure cleaner fuel an urgent one, the present Paper is submitted in the hope that a glance at the extent of the problem and a discussion of recent developments of coal-cleaning processes may help to shorten the path to the solution of a present-day difficulty.

Considered in a general way the difficulty in question has two aspects, a national aspect and an individual aspect. The Federation of British Industries published in a recent pamphlet the information that of the 60 million tons of coal used per annum in Great Britain for industrial purposes (exclusive of collieries) about three-quarters, so far as the Federation could ascertain, is slack coal; and as much as 89 per cent. of the total quantity used is unwashed. Assuming that the whole of the washed coal is slack, and allowing 10 per cent. for sea-borne coal, which we can for the moment afford to neglect, it still appears that about 35 million tons of uncleaned slack coal are transported by rail annually in Great Britain, for a distance on the average of, perhaps, 50 miles, to be used for steam raising and manufacturing purposes.

We have already seen that the present-day percentage of dirt in slack coal is on the average at least 5 per cent. more than the pre-war percentage. It follows that at least one and three-quarter million tons of material which is worse than useless (represented by 87,500,000 ton-miles of railway haulage) is annually transported up and down the country; absorbing labour to load it, labour to transport it, rolling-stock to carry it, labour to off-load it, labour to fill it into furnaces, and labour to take it out again as clinker. But the end is not even yet, for more men are required and more rolling-stock is utilised in disposing finally of the dirt by dumping it on the ash tip.

If the whole of this recently added 5 per cent. or more of dirt could be got rid of at the pit-head, about 2,000 trucks and 40 locomotives, together with all the man-power released, would be permanently available for some useful purpose. But no effort made to abolish the extra dirt, however painstaking, is likely to attain 100 per cent. efficiency, and it is not desired to overstrain a statistical argument. Sufficient may, however, have been said to secure general acceptance for the view that the problem of securing cleaner fuel has definitely a national aspect; the transport of dirty coal involves so much useless effort. That the same problem has an individual aspect is in need of no argument. The coal-cleaning problem is of importance to all who use coal, whether for steam raising or for manufacturing purposes. It is also clearly of the very first importance to those who undertake to meet the demand for coal.

It has been said that nearly 90 per cent. of the coal used for industrial purposes is unwashed, and the question arises what means has the supplier available to meet the demand for clean fuel? Coal washers of varied

design whose advantages and limitations are well known have been in use for many years, and it is no part of the present object to discuss them. The intention is merely to describe briefly two processes of recent development, one of which has the added interest that it is new in principle.

The chief difficulty in coal washing by the older methods is to deal effectively and efficiently with fines coal. The process just referred to as being new in principle offers a solution of this problem. The other process, on the other hand, attains an unusually high degree of efficiency in dealing with coals of all sizes from 2½ in. downwards. A proper combination of the two would seem to offer an adequate solution over the whole range of coal cleaning.

The Cleaning of Fines.—Coal washing has hitherto been effected by methods which depend in principle upon differences of specific gravity between coal and dirt. If the dirt is of the same or nearly the same specific gravity as the coal, what may be termed "specific gravity methods" fail when applied to material below a certain size. The new process for washing fines coal is independent of gravity. The coal to be treated, if not already fine enough, is crushed until the particles pass through a screen about one-tenth linear inch aperture. It is then mixed with three to four times its weight of water together with a small quantity of reagent. The reagent may be an oil or coal-tar product, and 1 lb. is, generally speaking, required for each ton of coal treated. The mixture is agitated by a power-driven mechanical mixer and a multitude of minute air-bubbles are produced. To these air-bubbles the coal particles attach themselves and they are floated by them to the surface of the water in the form of a thick coal-laden froth. The ash-forming dirt sinks to the bottom. The coal contained by the froth is removed by a suitable scraper and then dried for use. The dirt which sinks is drawn off and rejected.

Once the proper reagent has been found, the working of the flotation process is extremely simple and very effective. Given a steady flow of feed to the plant and a regular supply of reagent, a flotation machine will, it is claimed, produce clean coal on the one hand and, on the other, a residue which is very nearly coal-free, in a way which was described in a paper read recently before the Institution of Mining Engineers as "automatic, regular and persistent."

Apart from piping and valves and the mechanically-driven mixers and scrapers, the ordinary flotation machine is constructed entirely of wood. It consists usually of from five to ten "mixing" boxes, each with a "froth box" connected to it. The material under treatment passes from mixing-box No. 1 via froth box No. 1 to mixing box No. 2, thence via froth box No. 2 to mixing box No. 3, and so on through the plant, the final reject coming from the last froth box. A flotation machine to deal with 1,000 tons of coal in a 24-hour day measures approximately 37 ft. by 15 ft. 9 in. by 15 ft. 6 in.

The following typical separation was effected recently in the cleaning of Derbyshire top hard slack :—

—	Weight.	Ash.	Fixed Carbon.	Volatile Matter.
	per cent.			
Crude	100·0	29·55	48·2	22·35
Cleaned product ..	75·1	9·86	60·24	29·9
Reject	24·9	82·45	2·75	14·8

The Cleaning of Nut Coals.—The new process for cleaning coal other than "fines" comes to this country from Belgium. It is called the Rheolaveur process and its main features are :—

(1) The means used to carry the material to be washed through the washer, namely, a stream of water confined in a series of narrow troughs.

(2) The simple arrangement by which the process is controlled.

(3) The arrangements by which part of the material under treatment is automatically rewashed so that, in the ultimate result, a high degree of freedom from shale and dirt is attained.

A strong and steady flow of water is the first requirement of the process. The water is turned into a trough into which the coal to be treated is also led. The flow of water carries the coal along with it and the separation of the coal and dirt is effected by stratification, the rate of flow of water being so regulated and the trough of such a length as to allow time for the coal and dirt to stratify. Arrangements are made to draw off the dirt from the bottom of the trough at intervals, allowing the coal to be borne along, until, at the end of the trough, there is no more dirt to draw off and clean coal is delivered to the clean coal hoppers. At each drawing-off point a cast-iron box is inserted and a current of water (controlled by a hand-valve) is made to flow upwards from the bottom of the box into the trough to prevent coal from being drawn off with the dirt; serving a similar purpose to the upward flow of water in the washbox of the Draper washer. The water is stored in a tank fixed about 20 ft. above the trough and arranged to give a continuous steady flow of water.

In washing nuts the strength of the upward current of water in the first box is kept high so as to allow shale only to be drawn off. This shale forms the reject and it finds its way at once to the shale dump. In the second box the strength of the upward current of water is rather less so as to allow the balance of the shale, and it may be a little coal, to pass through the box. This reject is not sent to the shale dump; it is returned by means of an elevator to the original trough to be rewashed. In washing nuts two boxes only are necessary, the coal passing the second being dirt-free it is delivered therefrom via a moving drainage plate to the nut-coal bunker.

In washing small coal, four boxes and two lengths of trough, one above the other, are necessary, but the principle of working is the same.

The Rheolaveur process claims the following advantages: (1) Low initial cost; (2) low maintenance and running costs; (3) easy control of working; (4) absence of complicated mechanical parts; (5) economy of space.

Some at least, of these advantages must be conceded. There is one Rheolaveur plant in course of erection in this country by the Butterley Company.

The François Cementation Process.

By Harry Standish Ball, O.B.E., M.Sc.

Among the many advances in engineering during the last few years, that of cementation stands out prominently. Originally commenced in France sixty years ago, it was introduced into England in 1911 by Monsieur François, many developments having been made and patented by him. Prior to this, cementation was used mostly in connection with mining operations; its sphere of operations has, however, lately become enlarged to such an extent that it is being used to solve various types of engineering problems in many parts of the world.

To illustrate this statement, the process has recently been used for sinking through water bearing strata in England, sealing off leakages in a reservoir in Scotland, repairing the damaged shafts of the Lens Concession in France, consolidating the foundations of a foundry in the Ardennes, constructing an underground dam on the Rand, and cementing the retaining wall foundations of the Mazoe Dam, Rhodesia.

The principle of cementation is the injection of underground fissures with liquid cement under high pressure, such injection being continued until the fissures are completely filled and the water previously issuing therefrom sealed off. To effect this result, holes are bored by means of any of the well-known drilling machines, and upon a fissure being encountered, the boring rods are withdrawn and a pipe range leading to a high pressure cementation pump, capable of a pressure of 4,000 lb. per square inch, connected to the borehole. The chief application of cementation in mining is the sinking of shafts through watery strata, and, in such connection, it has practically superseded the freezing process. In addition to sinkings, the process is largely used in the sealing off of water leaking through shaft linings, the construction of underground dams, the extinguishing of underground fires, and the driving of drifts and adits in water-bearing ground.

In the majority of sinkings, ordinary cement injections under pressure are usually sufficient to deal with the water, the procedure being briefly as follows :—The shaft is sunk until it has almost reached the water level—previously ascertained by a test hole. A series of 2-in. pipes are then cemented into the shaft bottom for a distance of some 12 ft., and holes bored through them to a depth of approximately 90 ft., cement injections taking place whenever fissures are encountered, the water being controlled by a suitable arrangement of cocks and valves. When the ground has been efficiently treated, sinking proceeds in the usual manner until only a plug of 5 yards of treated ground remains, the shaft being lined with plain or reinforced concrete. This cycle of work is repeated until the watery strata has been successfully passed through. The great saving in pumping costs by the adoption of cementation is most apparent, and, in addition, the abolition of cast-iron tubbing is a point worthy of consideration.

Most types of ground can be efficiently dealt with by cementation, pure and simple, the only notable exception being new red sandstone. When this ground was first experimented on, it was found that, owing to the character of the sandstone being porous in addition to being fissured, it was impossible to seal off more than 50 per cent. of the water by cement injections. Many experiments were carried out to overcome this difficulty, and it was eventually found that if the ground was first treated with injections of aluminium sulphate and sodium silicate efficient cement injections would follow. The action of these chemicals is apparently two-fold, the resulting precipitate of aluminium silicate formed in the ground, acting both as a lubricant to the cement forcing its way through the pores and fissures of the sandstone, and as a cementing agent itself. The introduction of the chemicals mentioned forms the basis of the silicatisation and cementation process at present being used with great success at sinkings in Yorkshire. The photograph* shows a specimen of new red sandstone taken from a depth of 150 yards in which a fissure has been completely filled by cement. It is of interest to record that the collieries in England where cementation has been adopted have been rendered practically immune from risks of flooding—a factor of great importance during labour disputes.

An interesting adaptation of the process was recently made during the repairing of the damaged shaft linings in the pits belonging to the Lens Concession, the mines having been flooded by the Germans during the war by blowing gaps in the wooden tubbing below the permanent chalk water level. To deal with this situation, holes were bored around the shaft to a depth below the watery strata and cement injected at various depths. As a result, the fissures were entirely sealed off, thus rendering it possible to proceed with the dewatering of the mines and repairing of the tubbing by ordinary means.

Though cement grouting has been in vogue for a number of years, the introduction of high-pressure cementation pumps has considerably increased its field of application. Not only have cracks in walls been treated, foundations consolidated and reservoir leakages sealed, but the bed of a dam itself has been effectively treated, rendering a large amount of excavation unnecessary.

A case has recently occurred in Southern Rhodesia, where the cementation process was used for solidifying and rendering impervious the subtrata of the foundations to support the retaining wall of a dam. The rock immediately underlying the foundations consisted of a laminated and fissured bed of ironstone rock, lying on a base of acid igneous rock. Under ordinary conditions it would have been necessary to excavate a large quantity of the pervious rock, but this was rendered unnecessary by drilling a series of eighty-two holes down to the impermeable rock, and treating the fissured ground by cement injections. A total of 350 tons of cement was used in rendering the ground watertight.

Work of an unusual nature has lately been carried out in France, water-bearing gravel deposits having been converted into a species of concrete suitable for supporting heavy foundations, merely by injections from the surface of cement under pressure. In spite of the fact that cementation has only played an important role in engineering practice comparatively recently, its progress has been so rapid that it is difficult to forecast what fame may ultimately be achieved by this cementation process.

* Exhibited at the meeting.

SECTION VI.—WATERWORKS, SEWERAGE AND GASWORKS.

The Utilisation of Waste Heat in Gasworks.

By George Edward Stewart.

The low cost of steam raising, due to the availability of cheap fuel, and high efficiency of conversion of the potential energy in coal, seem to be the only reasons that have prevented the earlier application of waste heat recovery on a wide scale in the gas industry. With greater necessity for conservation of coal, and further economy in gas production, the prospects of securing in a simple manner financial benefits and technical efficiency by this means assume considerable importance.

The available sources of waste heat are as follows :—(1) In the sensible heat of the waste gases of the retort furnaces. (2) In the sensible heat of the blast products of water gas generators and the potential energy of producer gas contained. (3) In the sensible heat of the products leaving the plants.

Any energy recovered can be readily applied to the following purposes : (*a*) Power to the Works.—This is usually derived from steam generated from coke or coke breeze, fuels which are now receiving appreciation from outside consumers, and town gas engines. Convenience in transmission has already resulted in many works in a proportion of the power from these prime movers being transmitted by electricity. (*b*) In the supply of steam to effect the reaction in water-gas manufacture.

Carbonisation.—A ton of coal having a calorific value of 300 therms will furnish some 14 cwt. of fuel products for actual sale, in the form of gas, 68 therms; coke, 148 therms; and oil, 17 therms—i.e., a return of nearly 78 per cent. The remaining 22 per cent. is lost or used in the process as follows :—

1. Process losses amounting to 29 therms.

2. 6·8 therms pass away in the sensible heat of the crude gas and tar vapours leaving the retorts. Much of this is dissipated by radiation and absorbed by the liquefying of constituents. By the use of water tube gas condensers, an amount of heat equal to about one therm can be recovered as hot water at 135 deg. F., which can be utilised as boiler feed, preferably after further heating by exhaust steam.

3. Ten therms are wasted in the sensible heat of the flue gases leaving the retorts setting recuperators at a temperature of 1,000 deg. to 1,250 deg. F., and more in certain vertical retort plants without recuperation. From this source profitable heat recovery is easy. Combustion in retort settings is normally complete, a typical analysis being :—

	Per Cent.
CO_2	19·0
CO	Nil
O_2	0·4
N_2	80·6

Such a waste gas would carry away, per pound of fuel burnt, 3,580 B.Th.U. above atmospheric temperature or 2,510 B.Th.U. above 400 deg. F., with an initial temperature of 1,200 deg. F. Passed through a boiler of 70 per cent. efficiency the quantity of steam generated would equal 1·56 lb., at 100 lb. per square inch, per pound of fuel burnt; at 1,000 deg. F., the quantity would still be 1·1 lb. or 490 lb. and 350 lb. of steam respectively per ton of coal, the exit gases in each case being 400 deg. F.

A reduction of flue gas temperature by 800 deg. at the base of the chimney reduces the draught from 17·5 tenths to 14 tenths, which is a factor to be remembered, as the boiler may cause further loss by back pressure. Reduction below 400 deg. F. necessitates the installation of induced draught plant and involves difficulties with corrosion, arising from the sulphur content of the gases. Such boilers are being successfully applied: On inclined retorts at Brentford, 2,900 lb. of steam per hour being produced per 3 tons of coal carbonised. On Woodall-Duckham verticals at Birmingham, yields of 500 lb. of steam per ton of coal are being obtained from installation handling over 400 tons of coal daily (800 gallons to 1,000 gallons per hour). With Glover-West retorts at Macclesfield, 700 lb. of steam per ton are being obtained. In considering results of this nature, it should be remembered that the efficiency of steam production is relative to the inefficiency of regeneration in the carbonising plant.

4. A net loss of 9 therms is incurred in the sensible heat of the coke discharged from the retorts at a temperature of 1,800 deg. F., after a portion of the hot coke has been returned to the producers. In continuous verticals

the coke is discharged from the retort at a low temperature, giving a loss of about 2·3 therms only, but the extracted heat is usually used for heating the air to the retort producers, in place of the waste gases which give a corresponding increased recoverable loss.

Recently, a Swiss firm has introduced a process in which successive charges of hot coke are passed through a large container. After each filling this is sealed and the enclosed air becomes converted to carbon dioxide and nitrogen. These inert gases are circulated through the contained coke and an adjacent waste heat boiler, until the temperature of the coke is reduced to 400 deg. F. Results from the installation of this process at Zurich and elsewhere show that 600 lb. to 800 lb. of 140 lb. pressure steam can be generated per ton of coke, equal to 300 lb. to 400 lb. per ton of coal (3·5 therms to 4·7 therms recovered).

5. The heat usually required on works for power generation is about 12 therms, and as the chief business of a gas undertaking is to produce fuel, it represents a loss of sale products. The equivalent quantity of steam represented is some 600 lb. per ton of coal, which is generally employed uneconomically in scattered small units, and could be reduced considerably by the adoption of electric transmission. All power could then be generated by efficient steam engines with, possibly, a small proportion of gas engine generators. More than sufficient steam could be derived from waste heat sources, thus: (*a*) Feed water from gas condensers further heated by exhaust steam. (*b*) 350 lb. to 450 lb. per ton from boilers at retort house chimney base. (*c*) 300 lb. to 400 lb. per ton from hot coke.

Assuming a value for steam of only 1*l.* per 1,000 gallons evaporated, the saving indicated by the use of waste heat boilers applied to the works power demand is equal to 14·4*d.* per ton of coal or 0·2*d.* per therm.

simple to extract heat from the blast products only, as, by reason of their temperature, they must not pass through tubes traversed by tarry gases. A considerable proportion of the steam to operate the whole plant can be obtained. Waste heat boilers are at work in England, on plants using two gallons of oil per 1,000 cub. ft., producing 45 lb. to 60 lb. of steam (at 90 lb. pressure) per 1,000 cub. ft. of gas made.

Waste Heat Boilers.—All the forms of waste heat boiler referred to are of the tubular type, often fire tubes, and because of the conditions of heating are large for their output. Specialist design is necessary. All this makes for higher capital costs, which, however, are offset by the entire absence of fuel charges and decreased labour cost. Maintenance and water softening charges average the same as for ordinary water-tube boilers. The saving of 0·2*d.* to 0·7*d.* per therm usually repays the outlay in two to five years, and adoption ought to be rapid on this account, no less then the raising of gas-making efficiency to 82 per cent. in carbonisation and 70 per cent. in gasification.

Desiderata in the Qualities of Town's Gas.

By John Sidney Gordon Thomas, D.Sc.

To be adequate, three main aspects of the question should be embraced in any discussion relating to "Desiderata in the Qualities of Town's Gas": (1) Economic production and distribution; (2) chemical and physical characteristics of the various products of the thermal treatment of coal; and (3) efficient utilisation of the same. The Conference, it is hoped, will afford an opportunity for the discussion of the question from these several standpoints.

Town's gas is the misnomer which poverty of language compels us to apply to one of the main products of the has been such that such combustion entails no permanent increase in the world's supply of atmospheric carbon dioxide. The consideration advanced indicates the desirability of eliminating as completely as possible from town's gas all sulphur compounds. As an economic proposition the sulphur content of town's gas present either as gas or vapour can be reduced to the equivalent of about 0·03 per cent. by weight, and more recent work has established the fact that reduction to a mere trace can be achieved industrially. Apart from certain obvious advantages accruing to this almost complete elimination of sulphur compounds, reference may here be made to the recent work of Travers,* who has shown that the clouding of soft soda glass during lamp working employing town's gas, is attributable to the presence of minute traces of sulphur compounds in the gas.

The second postulate I would make is that, subject to considerations of economic production, the constitution of coal gas and its mode of distribution and utilisation should be such as to involve the minimum needless expenditure or degradation of energy. Natural processes are all effected in accordance with this principle, which may be conveniently referred to as the principle of least action, a bedrock principle of physical and mathematical science. One can but contrast the apparent ease with which enormous volumes of water are transported and distributed over continents in the form of clouds and rain with the difficulties inherent to the best systems that man has yet achieved in its transport and distribution over very much more moderate areas. The principle would indicate that, economic considerations of production apart, the constitution of town's gas should be such that the expenditure of energy necessary for the storage and distribution per unit of gaseous energy is a minimum, subject to the proviso that the efficiency of utilisation of all degrees of concentration

DESIDERATA IN THE QUALITIES OF TOWN'S GAS.

Table giving the Physical Constants of the Principal Combustible Constituents of Coal.

Constituent.	Density.		Volume of Air Necessary for Complete Combustion of 1 Volume of Gas.	Calorific Power per Cub. Ft. (Dry) at 60 Deg. F. an 30-in. Pressure. B.Th.U.		Concentration of Calorific Energy in Mixture for Complete Combustion (B.Th.U. Gross per Cubic Foot).	Theoretical Temperature attainable by Complete Combustion (Deg. C.) with Air assuming Absence of Dissociation.	Volume of Products of Combustion Measured at Flame Temperature Derived from Combustion of 1 Volume of Gas.	Concentration of Calorific energy per Unit Volume of the Products of Combustion (Net).	Percentage of Gas Contained in Explosive Mixture with Air.		Maximum Velocity of Propagation of Flame, in Mixture of Gas with Air (in Tube 2·5 Cm. Diameter) Cm./Sec.	Percentage of Gas Present in Mixture in which flame is Propagated with Maximum Velocity.	Percentage of Gas Present in Mixture for Complete Combustion.	Percentage Thermal Radiation from Non-luminous Flame.	Wave-length corresponding to Maximum of Principal Band of Infra Red Emission Spectrum (10–4 Cm.).	Relative Intensities of Infra Red Radiation Due to Combustion in Flame.
	Grms. per Litre at 0 Deg.C and 760 mm.	Air=1.		Gross.	Net.					Min.	Max.						
Carbon Monoxide	1·2504	0·9672	2·38	323·5	323·5	95·7	2,100	25·0	12·9	12·3	75·0	60	per cent. 45—50	per cent. 29·5	per cent. 8·74	4·32	3
Hydrogen ..	0·08987	0·06952	2·38	325·2	271·9	96·2	1,960	23·6	11·5	4·2	75·0	480	38	29·5	3·63	2·61	1
Methane ..	0·7168	0·5544	9·52	1017·0	911·0	95·7	1,830	81·0	11·2	5·5	13·3	66	9·5	9·5	5·15	—	—
Ethylene ..	1·274	0·985	14·3	1599·0	1491·0	104·5	2,200	138·0	10·8	4·0	15·0	—	—	—	5·12	—	—
Benzene ..	3·482	2·694	35·7	3699·0	3542·0	100·8	2,460	372·0	9·5	2·5	6·5	—	—	—	—	—	—

Water Gas Manufacture.—Assuming a quantity of coke charged into the generators of calorific value 100 therms, an amount sufficient to produce 22,700 cub. ft. of gas, the thermal distribution is:—

1. Eight therms lost in radiation and convection, in hot ashes, and in coke dust in blast products.

2. 10·3 therms lost in the sensible heat of blast gases escaping.

3. The producer gas necessarily formed in blowing and normally passing away unburnt has a potential combustion energy of 15·6 therms. When the gas is carburetted by oil, a proportion of this up to 4 therms is employed for carburettor heating.

4. 6·1 therms passing away as sensible heat in the water gas made.

5. There is a further charge on the plant equal to 27 therms as fuel used in the steam-raising plant. Of this amount, 7 therms are lost in the boiler plant, 8·1 therms go to the generators as reaction steam, and 11·9 therms as steam for driving gas exhausters, blowers, pumps, &c. The calorific value of the uncarburetted gas produced is 68·1 therms, an overall efficiency of 53 per cent., being thus attained. When the gas is carburetted, the thermal efficiency rises towards 65 per cent., as the gasification of the oil is effected at high efficiency. With a loss of 39 per cent. of the original energy, waste heat recovery is becoming standard practice in America and this country. On the Fulham works one such boiler has been in operation nearly two years, evaporating up to 800 gallons per hour, with entire absence of operation trouble. Two cases arise:—

(*a*) "*Blue Water Gas.*"—In this process the whole of the issuing gases can be passed through the boiler, and the losses (2), (3) and (4), totalling 32 therms, absorbed in part, the gases leaving the boiler at 400 deg. F. 22·7 therms are recovered as steam, equal to 90 lb. per 1,000 cub. ft. The plant steam requirements being only 20 therms, or 79 lb. per 1,000 cub. ft., the boiler will generate more than the requisite amount of steam, resulting in an overall gasification efficiency of 68 per cent. to 70 per cent. The actual saving thus effected is over 2*d.* per 1,000 cub. ft. of gas, or 0·66*d.* per therm of gas produced, which repays the cost of the installation in just over two years.

(*b*) "*Carburetted Water Gas.*"—Boilers are working in America to utilise the whole of the heat wasted in this process, the steam yield being 80 lb. of high pressure steam per 1,000 cub. ft. In general, however, it is more

thermal treatment of coal in gas works. Nowadays, the energy of gaseous fuel finds application in such a diversity of directions that the designation "town's," referring implicitly to the use of the commodity as administering to the communal welfare more especially in the matter of the provision of light and heat for public and domestic purposes, is inadequate. One does not speak of "town's" electricity. Nor can the appellation "gas" be regarded as entirely satisfactory, as it rather serves to obscure what is of the very essence of the present discussion—namely, that town's "gas" is a mixture, not only of the more permanent "gases," but contains also the unsaturated or saturated vapours of certain liquids, and even of solids. These two aspects of the question—the complex nature and the diversity of manners of application of the product—adumbrate the complexity of the considerations involved in arriving at a decision as to what are the desiderata in the qualities of town's gas. The recommendations of the Fuel Research Board as embodied in the legal enactments of the Gas Regulation Bill, whereby considerable latitude is permitted to gas companies throughout the country in the matter of the production of gaseous energy of a declared concentration, and whereby the onus for the efficient utilisation thereof is to be borne by the gas companies, have, I think, somewhat simplified the problem.

In such a contentious matter as the present can any fundamental postulates be made, based preferably upon consideration of natural processes, which shall serve as the lodestar to guide the gas industry in its endeavour to serve national interests in the matter of the production of gaseous energy? "To the solid ground of Nature trusts the mind which builds for aye." I think there are at least two such postulates. From the nature of its origin town's gas necessarily consists of certain elementary gases, oxides of carbon, hydrocarbon gases and vapours, and small quantities of other vapours generally classified as impurities. The postulate will, I think, be accepted that the constituents of town's gas should, subject to economic considerations, be such that the products of their combustion should be carbon dioxide and water only, accompanied, if desired, by nitrogen and oxygen—products present in the atmosphere or discharged into the atmosphere during the operation of universally distributed natural processes, more especially those of respiration (a form of combustion) and evaporation. The evolution of the plant kingdom of gaseous energy is the same. The admirable work of the Gas Investigation Committee of the Institution of Gas Engineers leaves little doubt that over a wide range of concentration of gaseous energy the efficiency in use of town's gas does not vary appreciably. This arises largely owing to the fact, to which attention was, I think, first directed by Sir Dugald Clerk, that the actual concentration of gaseous energy in the *mixture* of gas and air necessary for its combustion is dependent only to a very slight degree upon the calorific concentration of the gas itself. Subject, then, to economic conditions of production, it appears that town's gas should contain the minimum admixture of those gases classified generally as inerts, more especially nitrogen and carbon dioxide (recent investigations tend to exclude oxygen from amongst the inerts). There appears to be very little justification from the purely physical standpoint for employing energy for the transmission, from the point of production to the point of utilisation, of gases already available in practically unlimited amount at the latter place. If merely carrying coals to Newcastle is inadvisable, what shall be said of delivering dross at that port? At the present stage of the evolution of the gas industry, however, it appears undesirable that any legal restriction should be placed upon the permissible percentage of inerts present in town's gas. The consumer is efficiently protected by the "declared calorific value" of the gas, and the gas company has to safeguard that the consumers' appliances are such that the gaseous energy, of the concentration supplied, may be efficiently utilised. It appears, therefore, that the question of the possible legal enactment of a limitation in the permissible percentage of inerts in town's gas must wait upon further investigation into the economic production of gaseous energy—a conclusion in keeping with the liberty intended to be conferred upon the gas industry by the recent recommendations of the Fuel Research Board. Naphthalene and cyanogen should be eliminated as completely as possible owing to difficulties of distribution and utilisation of town's gas due to their presence.

Should any restriction be laid upon the permissible percentages of the various combustible constituents present in town's gas? It seems to be generally overlooked that the possibility of almost infinite variation in the constitution of town's gas confers upon that

* Society of Glass Technology, March 16, 1921; see Engineering, vol. cxi, page 356 (March 25, 1921).

commodity a flexibility in application not possessed by its keenest competitor—electrical energy. The actual composition of town's gas can be varied within wide limits, the mixture remaining of constant calorific value. If the operation of consumers' appliances at the maximum efficiency requires the utilisation of gaseous energy at a definite constant hourly rate, then constancy of calorific value must be accompanied by constancy of the ratio of the pressure of supply to the density of the gas supplied. If, as seems desirable from a variety of considerations, the pressure of supply is maintained constant, then the density of the supply should be maintained as constant as possible. Subject to this proviso, I see no reason why, at the present stage in the evolution of the gas industry, any restriction of the nature referred to should be imposed upon the industry.

The physical constants relating to the principal combustible constituents of coal gas given in the table on the opposite page will, it is hoped, be of value in the discussion.

SECTION VII.—ELECTRICITY WORKS AND POWER TRANSMISSION.

Low Power Factor.

By Reginald Otto Kapp, B.Sc.

The principal disadvantages of a low power-factor from the supply engineer's point of view are :—

1. The capital cost of the electrical part of an undertaking is inversely proportional to the power factor. If the cost of this part is 15*l.* per k.v.a. of maximum demand, which is a moderate figure, this becomes 18·8 per kw. of maximum demand at a power facto. of 0·8. So the bad power factor necessitates an additional expenditure of 3*l.* 8*s.* per kw. The capital charges on this at 15 per cent. are 137*d.* per year. If the load factor is 25 per cent., a maximum demand of 1 kw. represents about 2,200 units sold per year, and the bad power factor costs us 0·062*d.* per unit. If the tariff was worked out on the assumption that the average power factor would be 0·8, it would pay the undertaking to offer a rebate of anything up to, roughly, 5*s.* per 1,000 units to any consumer improving his power factor to unity.

2. Wherever the station bus-bars are subdivided by reactances and power has to be supplied from one bus-bar section to another, which is the normal working condition, it will be found that with a bad power factor the regulation is very bad and the alternators on the more heavily-loaded sections supply an undue proportion of wattless current, so that the alternators on this section, if designed for the average power factor of the system, are fully loaded while the steam turbines are not fully loaded. The result is high steam consumption.

3. Wherever a district has a high voltage supply through step-up and step-down transformers, the fluctuation of the consumer's volts is greatly increased by a bad power factor. If, for instance, the total impedence in the line is 15 per cent., the difference in volts between full load and no load will hardly be noticed at a power factor of unity, but it will be 10 per cent. at a power factor of 0·8. So a consumer having a bad power factor becomes a nuisance to his neighbours as well as an expense to the supply undertaking.

4. Unless special methods of power-factor improvement are installed the light load power factor is considerably worse than that at full load on most installations. In consequence the alternators are fully loaded and the turbines lightly loaded, and the steam consumption at light load such as during week-ends and during periods of trade depression is unduly high.

A low power factor has also other minor drawbacks, such as increased distribution losses.

The first of the points mentioned above is more important the larger the undertaking, as the cost of the distribution system increases the more the generation of electricity is centralised. Arguments 2 and 3 apply almost exclusively to large undertakings. It will be seen, therefore, that the question of power factor improvement is one of growing importance. We could sometimes neglect it in the past; we shall not be able to afford to neglect it on the super-power schemes of the future.

To be effective, power factor improvement must be carried out at the far end of feeders—that is, on the consumer's premises. There is no technical difficulty about this. A number of devices are on the market, and have been in use for many years, for this purpose. Their capital and running costs are generally much less than the cost of a bad power factor, so that their installation is commercially sound and in everybody's interest, as it must eventually result in cheapening electricity. The difficulties of supervision and divided responsibility make it undesirable for the supply undertaking to pay for devices which are accessories to the consumer's plant, and so the problem for the supply engineer is to devise a tariff which will cause the consumer to instal such devices.

To be effective, such a tariff must make sufficient difference between the electricity bill for a good and a bad power factor to make it worth the consumer's while to effect the necessary improvement; it must be simple and free from ambiguity; the consumer must be convinced that it is fair. It should be based on integrating or recording instruments rather than on indicating instruments, as the latter type of instrument may be giving anything but a fair average figure at the time when it is read. It must be possible to determine the quantities for which a charge is made with accuracy, and the instruments for doing this must be inexpensive.

A method of charging frequently employed is a slight extension of the usual two-part tariff. In addition to a small charge per unit a fixed charge per k.v.a. of maximum demand is made. This charge places power factor and load factor on the same basis, which is not quite justifiable. A bad load-factor affects the capital cost per unit sold of the whole undertaking, a bad power factor only that of the electrical part. On the other hand, a bad power factor has other drawbacks besides those of increasing the capital charges per unit. The power factor is under the consumer's control; generally the load factor is not. A tariff which deals jointly with both is not likely to make it sufficiently obvious to the consumer how he can reduce his bill by installing power-factor improving devices. Another drawback of this method of charging is that no satisfactory maximum demand k.v.a. meter is yet in use. Those used are really maximum current meters, so they depend on the constancy of the supply voltage for their accuracy.

The above disadvantages do not appear to be serious and have not prevented this system from being adopted by some undertakings, but other more direct methods would appear to meet the case better. One such is the well-known Arno tariff. This is a charge per unit consisting of two parts. The first part covers the works costs and as much of establishment charges and capital charges on the non-electrical part of the undertaking as is to be paid for by power consumers. The second part covers the capital charges on the electrical part of the undertaking. In the example given at the beginning of this note the cost of the electrical part was assumed to be 15*l.* per k.v.a The capital charges on this are 540*d.* a year. At 25 per cent. load factor and unity power factor, the sale of units is 2,200 per year. This is 0·25*d.* per kw.-hour. Let the first part of the tariff be 1*d.* per kw.-hour. The total charge would then be 1*d.* per kw.-hour + 0·25*d.* per k.v.a.-hour.

At unity power factor the consumer would pay 1·25*d.* per unit; at a power factor of 0·8 he would pay 1·312*d.* per unit. That is to say he would pay the 0·062*d.* more than his bad power factor costs the undertaking. A single meter is used in connection with the Arno tariff which integrates kw. hours plus a fraction of k.v.a. hours, so that the bill can be based on a single reading. A modification of this tariff was suggested by Mr. Barbagaleta in a communication to the Italian Association of Electrical Engineers, and later independently by Mr. C. G. Carrothers in *The Electrical Review* of April 1, 1921, in which two standard watt-hour meters are used, and a simple computation from their readings gives a very close approximation to the Arno charge, which is the scientifically accurate one.

All these methods suffer from one drawback. The consumer is paying for something of which he does not get the benefit; that is, he is paying in one way or another for the idle component of the power. No doubt if supply undertakings start an educational campaign consumers will eventually come to understand that such charges are not only fair, but to the interest of everyone concerned. They will find it much easier to understand this, however, if the adjustment takes the form of a bonus for a good power factor rather than a penalty for a bad one. It is suggested that tariffs should be based on the assumption that the average power factor will be 0·8. It is reasonable to expect consumers to have a power factor of this value without any special appliances, so very heavy penalties may be exacted for values below 0·8. If the consumer improves his power factor above 0·8 the supply undertaking should allow a bonus of so many pence per 1,000 units for every 1 per cent. by which the average power factor, as shown by the readings of two standard integrating watt-hour-meters, is improved.

SECTION I.—RAILWAYS, ROADS, BRIDGES AND TUNNELS.*

The Use of Reinforced Concrete on Railways.

By William Wylie Grierson, C.B.E., M.Inst.C.E.

The main consideration which has determined the wording of this paper is the obvious fact that any attempt at descriptive detail within the limits of a short note is not possible, and that discussion, even when extending to an hour or two's duration, must necessarily be conducted on broad lines.

Most British railway engineers have had personal experience of reinforced concrete and all will be acquainted with the general properties of the material, but it is a significant fact that its use on British railways is undoubtedly less than on railway systems in America and on the Continent. Differences in railway practice exist in all countries and even in the same country on different systems, and are no doubt to be largely accounted for by the varying character of the traffic, and by climatic conditions and other circumstances peculiar to individual countries and individual districts. Doubtless local conditions, such, for example, as the existence of gravel pits or other sources of suitable material for the making of concrete, may determine, on grounds of economy, the use of reinforced concrete in one district, whereas in another district the availability of good building stone or suitable brick clay or local steel manufactories may turn the scale in favour of the older form of construction. But, though this be so, the general lesser use of reinforced concrete on British railways already referred to cannot be explained by local considerations such as these, and reasons must be sought in other directions to account for the apparently different estimate in which the value of the material is held in Great Britain as compared with that in foreign countries, and it is this difference of opinion or practice which it is suggested would advantageously be made a prominent feature of discussion at the present Engineering Conference.

The writer has no definite knowledge of the relative extent to which reinforced concrete has been used by county, borough and municipal engineers in this country and abroad respectively, but the general questions which arise in favour of or against its use must be very much the same for the municipal engineer as those which present themselves to his professional colleague on the railway: the first to arise is naturally whether the slower adoption of a, comparatively speaking, new structural material is to be attributed to want of enterprise or to a sense of misgiving, possibly well-founded, that its behaviour and relative value from the point of view of economy, length of life and other practical considerations have yet to be learned by experience.

It is known that there are wide differences of opinion and, with a view to facilitating discussion, it is proposed as far as space will permit, to comment shortly on a few of the principal purposes for which reinforced concrete has been used on British railways and to append without comment a list of some others. Probably in no direction has reinforced concrete been used to a greater extent than in the form of piling, and in its buried state it hardly calls for comment; it is not likely to deteriorate through oxidation of the steel reinforcement; it is capable of sustaining a considerably greater weight than a timber pile of equal dimensions and its life is practically everlasting.

Reinforced concrete piles have, in recent years, been largely used to take the place of timber in the construction of wharves and jetties; their greater power to resist destructive stresses caused by the fall of the monkey enable them to be driven in ground which would be unsuited to a wooden pile; they may be expected to have a considerably longer life and are immune from the attack of the teredo worm which, on the British coast, is so destructive to almost every class of timber. Deterioration, however, of the outer skin and reinforcement is not uncommon and generally occurs between low and high water-mark and some few feet above, the cause being usually attributed to the penetration of salt water and air; if sufficient cover be allowed and the composition of the concrete be adequately rich, and the proportion of sand such as to reasonably ensure the filling in of all voids, deterioration should not occur.

Perhaps of chief interest both to the railway and municipal engineer is the use of reinforced concrete for bridges; these include the underbridge which carries a railway over which heavy locomotives pass at high speeds, the overbridge which carries vehicular traffic of moderate weight at moderate speeds, and the footbridge provided for the accommodation of pedestrians only. Comparatively few railway underbridges have been built in any country, and the reason is probably not far to seek; the effect of constant vibration resulting from the passage of heavy loads at high speeds, upon the grip of the concrete on the reinforcement has yet to be learned by experience, and the knowledge that the consequences of a failure might be specially serious, acts undoubtedly as a great deterrent. The examples of overbridges carrying vehicular traffic at moderate speeds are very much more numerous, and it is suggested that in nearly every case the inducement which has led to their construction is that of an anticipated economy either in first cost, in subsequent maintenance, or, as a consequence, of longer life. For footbridges, or other light structures, it hardly seems likely that reinforced concrete will be used to any great extent, as the cost of the requisite timbering for erection is relatively considerable when light structures have to be dealt with. One important consideration which will no doubt always tell against the use of reinforced concrete for railway bridge work is its want of adaptability to alteration or enlargement.

Quite a number of railway buildings, such as goods warehouses, general offices, engine sheds, coal stages, &c., have been built, and here again the consideration which would appear largely to determine the question in favour of or against the use of the material is that of ultimate cost. Where the first cost of brick or stone is not substantially greater, probably few engineers would use reinforced concrete, but, in a considerable number of cases, a substantial saving in first cost is undoubtedly effected and where the competing material is ordinary steelwork a substantial saving in maintenance may result.

The use of reinforced concrete fence posts is largely on the increase; they are heavier than creosoted timber and the first cost is slightly more, but a considerably longer life may be confidently anticipated and a substantial saving in this direction will no doubt ultimately result. Many railway companies have experimented with various designs of reinforced concrete sleepers, but none have hitherto been found to last for any length of time under heavy and frequent traffic conducted at high speeds. They are necessarily heavy, somewhat expensive, and the probability of their supplanting timber seems remote. The difficulty in the transport of telegraph poles is against their adoption, but, on the other hand, the use of reinforced concrete signal posts is increasing, and they appear to have a future before them.

Space will permit of reference only being made by means of the following list to some other railway purposes for which reinforced concrete is used :—

Permanent Way.
- Block sleepers.
- Crank beds.
- Gradient posts.
- Lamp posts.
- Load gauge posts.
- Mile posts.
- Point rollers blocks.
- Sign posts.
- Station name boards.
- Station name posts.
- Wheel beds.

Fencing and Gates.
- Boundary posts.
- Cattle pen posts.
- Gate posts.
- Wickets.

Drainage.
- Drinking troughs.
- Inspection chamber covers.

* This and the succeeding Notes to page 88 were read at the meetings at the Institution of Civil Engineers on Thursday, June 30, 1921.

The subject of this note is that of reinforced concrete, but it may not be out of place to enumerate purposes for which ordinary concrete is now being used to a greater or lesser extent for small articles of railway equipment in place of timber, brick, stoneware, earthenware, cast-iron, &c.,' to which, however, limits of space permit of reference only being made :—

Building Materials.	*Permanent Way.*
Building blocks of various sizes.	Block sleepers.
Platform paving.	*Drainage.*
Platform coping.	Gulley cover dished for grating.
Steps, 14 in. by 6½ in.	Inspection chamber bottoms.
Wall coping of various sizes.	Invert blocks for 15-in. and 18-in. culverts.
Window heads.	Cover do. do.
Window sills.	Pipes, 12-in. to 42-in.

IMPACT TESTS AND ALLOWANCES.

By HARRY JOHN FEREDAY.

IT is proposed to give here some suggestions for conducting tests which may be made in the future, in order to obtain, if possible, a new formula for impact effect, rather than to treat of those tests already made in this and other countries.

The stresses to be noted in a bridge are those produced by :—

1. Static dead load.
2. Elastic deformation of the material under dead load.
3. Static live load.
4. Elastic deformation of the material under static and dynamic live loads.
5. Rapid application of the live load.
6. Vibrations of the structure as a whole and those of its members produced by unbalanced locomotive drivers.
7. Shock caused by defective track and rolling-stock.
8. Wind.
9. Friction of bearings.
10. Changes of temperature.

There is no difficulty in recording the algebraic sum of the stresses in a member of a bridge produced during any instant of time by a live load. Dead load stresses in existing bridges cannot of course, be recorded, but those in new bridges can be recorded during erection, and it would be advisable to do so in future for important bridges, more particularly for those of the cantilever type.

In the subject under discussion it is only the stresses produced by the application of the live load with which we are concerned, but deformation stresses produced by live load must also be taken into account in drawing up a complete set of rules for guidance in design. If a sufficiently large number of records be taken on an old bridge under the usual traffic, the stress per square inch in any part is obtainable.

When taking stress records for the determination of impact effect for use in rules applicable to the design of new work, one of two courses can usually be followed. The first is to take a very large number of stress records in many of those parts of a large number of typical bridges, where the present knowledge of the subject leads us to expect the maximum stresses per square inch, including deformation stresses, employing typical locomotives at various speeds, from a crawl to the maximum speed permissible. From the records obtained the results can be plotted against loaded length and be included in two curves, whose ordinates will represent respectively (1) the maximum stresses per square inch produced by the static live load for any loaded length ; (2) the corresponding maximum stresses per square inch produced by the dynamic live load at the highest permissible or the critical speeds. The difference in the height of the ordinates for any loaded length is a measure of "impact effect."

From these two curves an empirical formula can be deduced which will give approximately the minimum permissible allowance for impact effect in the design of new work. It is obvious, however, that this formula can apply explicitly only to the particular types of bridges and locomotives used in taking the records, and while much information regarding the laws governing impact effects would be obtained during the necessary scrutiny and measurements of the records (which in time would probably lead to complete knowledge) such information is not essential.

It is necessary in measuring any two comparable ordinates in the two curves above referred to, that the points thereon should have been produced by the same position of the locomotive on the bridge. In taking the static live load stresses the time would be shortened if the so-called "crawl" was about 5 m.p.h., for at this and even higher speeds there is no appreciable impact effect. This method of dealing with impact effect is essentially practical and useful, and a formula produced by it will probably be the one in general use for some time until a more scientific one is evolved.

The other course to follow is the more scientific one, and consists in a much fuller analysis of records in order to trace to their origin the many minor curves, which, when added together algebraically, by the stress recorders, form the curve given on an ordinary stress record, and from an analysis of these minor curves to obtain the laws governing their production. Many records are very complicated, and it would be almost impossible to analyse them. It therefore becomes necessary to obtain records in which some of the minor curves are eliminated and to obtain other records where vibration curves only without stresses are recorded, so that the shape and frequency of the curves can be more accurately determined.

Very many stress records of bridge members have been obtained in different countries by the use of various types of instruments, and the experience gained from them is of inestimable value, and should of course be used in making further tests. From the investigation of such records it has been determined and is now accepted by engineers generally, that it is the unbalanced condition of the locomotive driving wheels which produces the greatest proportion of impact effect. The laws governing this effect have not yet been definitely formulated and much further knowledge is necessary, which can be obtained only by further tests.

It is desirable in such tests that the position of the cranks of the locomotive driving wheels should be in some pre-determined position on the bridge, but this is almost impossible to obtain in practice, and many runs may have to be made with the test train before the required position is hit upon by chance, and it is obvious that neither of the driving cranks may reach its lowest position on a span whose length is less than three-quarters the circumference of the driving wheel. Where, however, a bridge is composed of a series of short spans, or where a span has a series of rail-bearers, the instruments up to the number available might be attached each in a similar position on all the spans or rail-bearers, and the exact positions of the crank recorded by a mark made automatically on each of the records, so as to obtain from at least one of them a record of maximum effect. From such a series of records much valuable information would be obtained, and it may be possible from them to determine the law. If not, then other tests of an even more scientific nature may have to be undertaken. While obtaining this law, of which one factor is the unbalanced condition of the locomotive driving wheels, it would be advisable and, indeed, necessary to obtain another factor for the lateral oscillation of the locomotive producing vibrations of the structure in a lateral direction.

The author does not at present see any way of easily separating from the records the stresses produced in the bridge by the lateral oscillation of the locomotive, but their relative value for different types of locomotives might be obtained by using a seismograph (or by temporarily converting the stress recorder into one for the purpose), by which means vibrations would be recorded instead of stresses. To reduce the number of engine runs, deflection of the main girders should be taken under the static loads by a deflectometer, and from the record of such deflection the approximate critical speed should be calculated, and checked from the records.

The determination of a law for governing the effect of the sudden application of a rolling load to a bridge can probably be best determined by using a rolling load in which there are no reciprocating parts or in which they are balanced. A series of tests made with an electric train or with a four-cylinder locomotive over a series of bridges with a perfectly straight and even track, would go very far to establish the law. The stresses produced by the sudden application of the load are, however, very small. In conducting these tests the camber of the track on the bridge should be noted.

For carrying out such tests on bridges as here proposed a recording instrument is necessarily essential and the records of the stresses obtained should be of a permanent character. Moreover, the instrument must be of a stouter make than a laboratory instrument in order to withstand the shocks and vibrations to which bridge work is subjected by the passage of a high-speed train.

The records should show a base line, the length and division of which should be a measure of time and consequently also a measure of train speed ; and the recording line should show every vibration of stress, however caused, including the more rapid vibrations of minor parts of a bridge. The sets of instruments including the deflectometer, should all be capable of being synchronised, so that the records can all be automatically and instantaneously marked, at least with the exact time when the leading axle begins to affect the stresses in a bridge, and also when the last one ceases to do so. The lowest position of the driving-wheel cranks should also be permanently and automatically recorded on the record.

The synchronisation is very important because of the facility and celerity with which the records from the instruments can then be compared, and the actual speed of the train ascertained. In fact, the instruments should be such that they will record every vibration of stress while a locomotive is travelling over, say, a 5-ft. span or a rail-bearer, at 80 m.p.h. (occupying less than 1 second of time).

The selection of the positions for the instruments is important, because, whatever movement under a train load occurs in a member of a bridge, to which an instrument is attached, that movement has to be conveyed to the instrument through the points of attachment, and its amount varies very greatly in similar parts of the same span. The records obtained should be accompanied by very full data of particulars concerning the bridge, the locomotive, the position of the instrument, the conditions of the bearings and, where roller bearings are used, the position of the fixed end.

It would be unwise to predict the exact nature of a scientific formula for impact effect, but it will probably contain coefficients for type of bridge and of locomotives and one for the central deflection of the bridge under unit load, and may contain one for maximum speed. It is sometimes advanced by engineers that little is to be gained by further investigation of impact effect, on the grounds that a variation of, say, 10 per cent. above or below the Pencoyd formula is insignificant compared with the total of dead and live combined with impact as given by that formula ; but this attitude is untenable in a scientific age, and it is quite certain that if it were possible to calculate the maximum stresses which are likely to occur in any part of a new bridge, it would be permissible to stress the material in such a bridge to a much higher degree than is considered, with our present knowledge, to be desirable, thus resulting in an appreciable saving of material.

SECTION III.—MACHINERY.

THE INFLUENCE OF THE AUTOMATIC AND SEMI-AUTOMATIC MACHINE ON THE SKILL AND RESOURCEFULNESS OF THE MECHANIC AND OPERATOR.

By ARTHUR HENRY HALL, C.B.E., B.A., M.Inst.C.E.

BOTH automatic and semi-automatic machines have been a gradual development from the ordinary turning lathe, with the object of enabling increased output to be obtained on repetition work. Probably the two main features considered by the designer were production and flexibility. The two are not always compatible, and it will generally be found that the more completely automatic the machine the larger its potential output on work suited to its capacity, but the greater the difficulty in changing over from the manufacture of one article to another. These developments in design have practically eliminated the need for initiative on the part of the operator. In the extreme case, a full automatic machine requires only feeding with the material, while the capstan and turret lathe require the employment of labour merely to make them function in their predetermined cycle of operations.

Except in the case of machines designed for a single purpose, the variety of work now possible on a well-designed automatic or capstan lathe is such that ample scope is provided for the display of resource on the part of the mechanic. This quality is more a question of inherent ability than of training, and though long experience may increase aptitude up to a point, it is doubtful if this is not skill rather than resource.

It is well known that only a small percentage of good mechanics can set up and tool an automatic machine to the best advantage—the remainder in varying degrees lack the ingenuity necessary. The inference is a strong one, that the quality of the resource required differs to some extent from that shown on less specialised work. It is not, however, possible to consider this question fully without reference to the character of the works in which the machines are installed. Probably the highest degree of initiative is displayed by the mechanic in small engineering works, where facilities such as are provided in larger works are absent, even allowing for the fact that the machines may not be run at the high efficiency expected in a shop where a staff of specialists is employed.

The mechanic in such circumstances will probably have a variety of work to consider, the quantities in most instances being strictly limited, and he will not only have to decide on the type of tools, the speeds, feeds and methods of setting up, but he will learn to think in terms of time per cycle of operations. He may also have to determine whether the quantities to be made will justify the provision of special tools and cams, or whether a lower rate of production, with standard appliances and lower initial cost, will not be more economical.

In larger works the tendency is for the preliminaries to be done in the office, and the shop will be given the times, or even the actual operations will be detailed. The resource of the mechanic will be limited by such arrangements, just as the necessity for ingenious methods of adapting a tool to work for which it is not designed does not arise in a well-equipped tool room. The skill displayed by the operator varies with the class of tool, and on the semi-automatic machine in particular the aptitude shown is probably acquired unconsciously. The workman who obtains average results learns that he must not press his tools, or stoppages will reduce output, and he performs the cycle of operations in a manner that does not unduly exhaust his physical energy. The operator who gets the maximum output usually exhibits more than usual interest in the work, and his aptitude results in the expenditure of less energy, the latter probably by reason of a subconscious process which enables him to achieve a result approximating to that obtained by a close motion study of the work. In a woman operator, for some reason, the interest factor is more often sustained, and the tools wear longer because of her keener sense of touch. On light work, therefore, where physical exhaustion is not a potent factor, her output is often better than that of a man.

That the combination of interest and aptitude defines skill is clearly shown in the variety of defects which can be produced by an inexpert workman. It is also noticeable that where the makers of a machine wish to demonstrate what can be produced, it is usual for the workman to be a mechanic, or an operator of exceptional intelligence. The mechanic's function of putting the machine into the condition for successful operation may be considered under two heads—the setting up, and the provision of tools. The first is specialists' work—the variation in the time taken by different mechanics in getting similar machines to run being an indication that a high degree of skill is necessary. The provision of extremely accurate yet robust tools calls for skill analogous to that of other tool-room work.

The conclusions of the writer are, therefore, that the designer has precluded the operator from the display of resource, but that a reasonable amount of skill is required. The mechanic must display great resource, the amount varying with the degree of responsibility allotted to him by the management in the matter of design and lay-out of tools. His skill in making these is of the kind usually expected of a highly trained workman, but in setting them up he may exhibit qualities not readily capable of comparison with those required in other work. It is suggested that amongst the points, which might be advantageously amplified by discussion, are the following :—

1. The degree of skill exhibited by the operator in dealing with different qualities of material, especially

the very hard alloy steels used in motor-car and aeroplane construction.

2. The skill displayed by women in similar conditions and generally.

3. The effect on the initiative of the mechanic :—

(*a*) Of highly specialised machines with definite limitations in their scope.

(*b*) Of the practice in large works of detailing the operations in the office.

Mechanical Appliances and Labour in Loading and Unloading Ships' Cargoes.

By Arthur Musker, M.Inst.C.E.

This note is not intended to be a description of existing mechanical appliances, but rather to promote discussion upon how much more mechanical appliances could be used, and to show how many docks lack up-to-date methods in this respect.

As an example of considerable importance take the bunkering of steamers from barges in the London docks. It is no exaggeration to say that over 3,000,000 tons of coal per annum are raised from barges by means of crude steam winches and boilers ; the coal being shovelled by hand into wickerwork baskets. There are some large appliances used for this purpose, but being unwieldy and difficult to move from dock to dock they only do a small portion of the work required. A full gang of 15 men and 1 boilerman put the coal into the bunker hatches at the rate of 45 tons per hour, and taking the present state of labour into consideration, it should surely be possible to improve the system.

If the handling of the goods is followed from the time they are put into the ship to the time they are put on a barge, cart, or railway truck after being discharged, a visit to any ordinary dock shows a fearful lack of mechanical appliances which could take the place of manual labour. The goods appear to be stowed in the steamer in the first instance with an utter want of thought as to how they are to be discharged and distributed to save labour. One sees in the same sling packages or bales addressed to different consignees, which have to be trucked separately to the various positions set out in the warehouse ; and it does not appear impossible that a little forethought and arrangement when loading would prevent this. When discharged, they are handled in small units by a man with an ordinary truck, sometimes being run over rough concrete roads and rough wooden floors in the warehouse. Warehouses are built low, and the goods are only stowed in tiers four or five bales high ; all being done by hand. The loss of time one sees owing to the men having to wait on one another is appalling. To keep up-to-date and handle warehouse goods economically, warehouses, if not suitable, should, like old machinery, be scrapped.

A striking instance of what could be done is given in an article in Engineering (pages 541 and 576, vol. cxi.), describing the appliances used in handling goods at the Port of Manchester warehouses, where they have overhead cranes, electric trucks, conveyors, stacking machines and numerous others ; and in my opinion other docks would do well to follow this example.

Why should not electrical trucks be used in place of hand trucks ? and why should not careful attention be paid to the floors over which they have to run ? On the other hand, why should not ordinary wheel trucks, to carry about 10 cwt to 15 cwt., be fitted with ball bearings, so that each load lowered by the crane could be moved to its destination by one man, instead of its being split up into hand truck loads of say, 2 cwt., one man to each ? I have proved that with a reasonably smooth floor and a well designed truck, 20 cwt. can be easily moved by one man. Even in the slings used for lifting the goods there is a want of attention to detail ; one sees almost every lift a sling used about 8 ft. or 10 ft. too long, which means that the crane, as a rule, lifts 8 ft. to 10 ft. higher than is necessary, probably wasting 25 per cent. of the power required.

The discharge of frozen meat is an important item, and although in some cases conveyors are used, it is to a very limited extent, and I suggest for discussion that the continuous conveyor, as against the intermittent crane system, might be extended with considerable advantage as regards economy in time and labour, as against the prevailing system of slinging, lifting and lowering by means of cranes, then loading on to a hand truck and wheeled over rough roads to the cart or railway wagon. I have seen at Victoria Docks two quarters of beef wheeled for about 100 yards to a stage, where each quarter was lifted by four men from the truck on to the shoulders of one man and carried out to the van to additional men to be placed in position.

More attention might be paid to the hatches of steamers and doing away with the stanchions in the holds, in order to facilitate getting in and out and stowing the cargo. Whether the above want of applicances is due to the shipowners, shippers, stevedores, dock companies, or difficulties with labour, is an open question. Whether it is due to (as is often the case) the loading and discharging of the cargoes being paid for by a percentage on the cost of carrying out the work is also an open question, but undoubtedly it is a system that does not tend to either rapid or economical working.

Should not dock warehouses in all cases be built high enough to store goods a height of 15 ft. to 20 ft., the goods being raised or lowered by mechanical appliances ?

It must be understood that the criticisms I have made do not necessarily imply that the engineers of the port authorities, stevedores, shipowners, shipbuilders, &c., do not know their business, but I do say that there must exist a want of consultation and of conferring between the different interests which prevents improvement in the loading and discharging of ships' cargoes as at present carried out.

I suggest that if the engineers of the various interests have not the time to study the questions together, it would pay them and the country generally to employ expert engineers to obtain the views of the various interests, combine them, and prepare schemes for economically handling cargoes in the various docks, of goods of various characters. Owing to the courtesy of Mr. Kirkpatrick, engineer of the Port of London Authority, it is proposed to visit the Victoria and Albert Docks, and I suggest that if possible the unloading and warehousing of the cargoes of some of the steamers should be closely followed, and would be pleased to hear whether my views are correct.

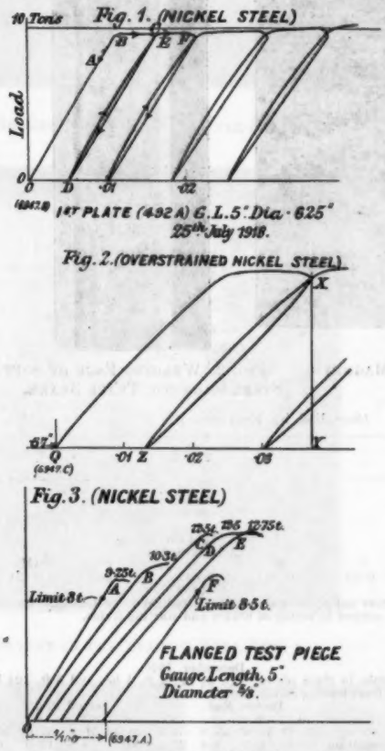
SECTION IV.—MINING AND METALLURGICAL PROCESSES.

The Elastic Limit.

By Professor William Ernest Dalby, M.A., B.Sc., F.R.S., M.Inst.C.E.

The difficulty of defining the elastic limit is due to the fact that the term is used in more than one sense by engineers. Without traversing the various uses of the term, it will be generally agreed that the term elasticity, in its broad sense, means the power of a material to recover its primitive form after loading has been applied and removed. Recovery may be partial or complete. The power of complete recovery is lost when the stress produced by loading has once passed beyond a certain limiting value peculiar to the material.

Below this limiting stress the extension of a steel



test-piece is proportional to the load producing the extension. Above this limiting stress the extension increases at a greater rate than the load. This limit, therefore, is called the limit of proportionality, and the term elastic limit is often used to define this point. This use of the term, the most general one, would seem to convey that the elastic power of the material is exhausted when once the stress has passed beyond the elastic limit, and the material has passed into a plastic state. This is by no means true. The material possesses elastic properties right up to the instant of fracture.

If a test-piece, loaded nearly to the point of fracture, is watched in the testing machine, and the load is quickly removed, the test-piece will spring back and to all appearances behaves as a perfect spring. Definite measurement shows, however, that the relation between stress and strain is unproportional. The test-piece shrinks towards its primitive dimensions unproportionally and fails to get to its primitive dimension by the amount of the permanent set. I have used the term unproportional elasticity to describe the state of the material in these circumstances.

To illustrate this point and some others, I throw on the screen a diagram, taken automatically in one of my recorders. The test-piece was new material and in the proportionally elastic state. Starting from zero the spot of light moved along a straight line to the point marking the limit of proportionality. The line then bent away and then the material yielded. The inner state of the material alters as the stress passes through the limit of proportionality. One state merges into the other.

If the loading be stopped at any point after this limit has been passed, and then removed and afterwards reapplied, the process involves the doing of work on the inner structure of the material, and the record of the process is a loop, the area of which represents the work done. The curved boundaries of the loop record the act that in reloading the strain increases at a greater rate than the stress. And in unloading the material shrinks at a greater rate than the reduction of the load. The first elastic hysteresis loop described by the process of unloading and reloading is the first step towards the breakdown of the material by fatigue.

From a practical point of view, therefore, the term elastic limit should mean the limit where proportional elasticity ends and unproportional elasticity begins. Unloading from any load below this limit and reloading can be done without describing a hysteresis loop. Unloading and loading, once the limit has been passed is always accompanied by an elastic hysteresis loop.

I illustrate this by a few lantern slides of diagrams I have taken from various materials.

Diagrams of this sort provide new data for the engineer from which to estimate the quality of the material. The new data are the area of the loops and the rate of increase of area. I have taken a succession of loops on several materials up to the point of fracture, and find that the area increases at first rapidly in some material s and then tends towards a limiting value. A typical instance of this is shown in Fig. 1, herewith. For details of these experiments see "Researches on the Elastic Properties and the Plastic Extension of Metals," Phil. Trans., Series A, vol. ccxxi, 1920.

Inner structure and elastic limit are mutually dependent. The microphotograph [not reproduced, Ed. E.] of the inner structure of a piece of mild steel containing about 0·13 per cent. carbon, shows the blocks to be of enormous size. The L.E. diagram corresponding to this shows the low yield-point, and therefore low elastic limit of 9·2 tons per square inch. The material was suitably heat treated to refine the structure, and then the yield point leapt up to 18 tons per square inch.

High elastic limit steel is produced by heat treatment designed to refine the inner structure. The temperatures defining the heat treatment are not obvious or the same for all steels, in fact each steel requires special investigation of its thermal properties by means of cooling curves to find the regions of the necessary temperatures.

I should like to refer briefly to one point in conclusion. Proportional elasticity is destroyed by overstrain. A diagram illustrating this condition is reproduced in Fig. 2. The term overstrain means that the material has been loaded to the extent required to pass it into the condition of unproportional elasticity.

The behaviour of irons and steels differs after overstrain. It is known that iron and soft steels tend to recover their property of proportional elasticity by mere lapse of time. And the state is reproduced in very short time by moderate heating as, for example, by mere boiling in water. But the hard steels and the alloy steels do not share this property. After overstrain they remain in that state without recovery indefinitely, and recovery can only be brought about by heating to high temperatures.

I cite one example. The material is nickel steel, the curves being shown in Fig. 3 herewith. The elastic line of a fresh test-piece is shown at A. The piece was stretched 2 per cent. and then a diagram taken, line B. The curvature shows a state of unproportional elasticity. Line C was taken after stretching to 6 per cent. Line D is a repetition test after a rest of 24 hours. In another test the lapse of time was one year. But in this example there was no restoration of proportional elasticity. Line E the diagram after boiling the piece in water—no effect. Line F taken after heating the piece to 550 deg. C. in a muffle for an hour. The elasticity recovery is perfect.

These few remarks will, I hope, show that the exact definition of the term "elastic limit," is a matter of some difficulty, because of the current use of the term in several cases. The term limit of proportionality may be used for the exact definition of one point in the load extension diagram, without interfering with the present uses of the term elastic limit. The limit of proportionality of a material is not a fixed point, but varies with heat treatment and vanishes with overstrain.

The Effects of Scratches in Materials.

By Professor Ernest George Coker, M.A., D.Sc., F.R.S., M.Inst.C.E.

The importance of having a smooth surface in metals exposed to a high stress has been recognised by many engineers who impart a high degree of finish to their work, especially in cases where an intense stress varies cyclically, as in the moving parts of high-speed machinery. The increased strength and extension due to a high degree of polish in a tension test-piece has also been frequently noted, and the elimination of scratches appears to be of importance in many other cases.

The effect of a surface scratch in a stressed material is, therefore, a problem of great interest and in general of considerable complexity. It has already received the attention of several investigators, and especially recently of Griffith,* who has also examined the effects of minute cracks in the interior of materials where the conditions are even more complex.

It is probable that little is lost by making as simple assumptions as possible in examining this problem, and in the great majority of practical cases it seems likely that the scratches produced by ordinary machining operations may be considered as minute notches in the surface, probably with plane or curved sides inclined at a considerable angle and rounded off at the bottom of the

* A. A. Griffith, "The Phenomenon of Rupture and Flow in Solids," Phil. Trans. Roy. Soc., Series A, vol. ccxxi. 1920.

DAMAGE TO TYRES AND RAILS BY BRAKES OR SLIPPING WHEELS.

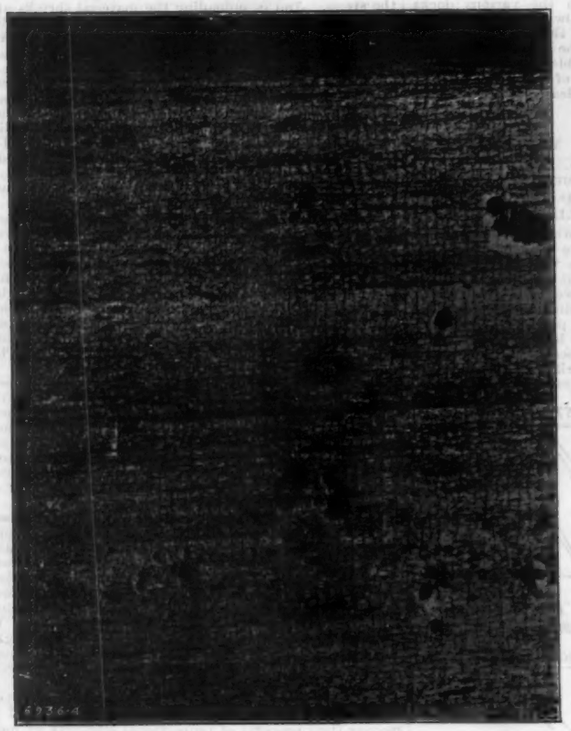


FIG. 1. SURFACE OF TRAM RAIL ACTED ON BY MAGNETIC TRACK BRAKES. × 2.

FIG. 2. WEARING FACE OF SOFT STEEL MAGNETIC TRACK BRAKE. × 2/3.

FIG. 3. SURFACE OF TRAM TYRE ACTED ON BY SLIPPER BRAKE. × 3.

PARTICULARS OF BROKEN RAILS. (Supplied by Engineers.)

—	Rail A.	Rail B.
Original weight per yard ..	96 lb.	90 lb.
Length	44 ft. 8 in.	30 ft.
Weight per yard when broken	84 lb.	79·4 lb.
Steel process	Acid Bessemer	Acid Bessemer
Analysis	C. 0·40, Si. 0·110, S. 0·071, P. 0·065, Mn. 1·02	C. 0·49, Si. 0·47, S. 0·045, P. 0·065, Mn. 1·24
Laid in track	1908	1893
Position, &c.	Inner rail on sharp and steep incline. Near home signal at a junction. Trains frequently stopped. Wheels often slip on restarting.	Inner rail on 50-chain curve. Gradient 1 in 69 rising. Rail was subject to action of brakes and starting trains.
Date when broken ..	April, 1920.	December, 1920.
Number and position of fractures	Broke in four places	Broke in three places, 2 ft. 3½ in., 4 ft. ½ in., and 5 ft. 10½ in., from leading end.
Tensile tests from broken rail	Top Flange. / Bottom Flange.	Broken End. a b c d / Sound End. a b c d
U. stress ..	51·3 / 51·8	25·6* 55·6 45·9 54·2 / 28·4† 51·9 51·0 56·7
Elongation ..	24·3 / 23·3	0·5 4·2 1·8 33·2 / Nil 3·5 13·0 6·5

* Flaw 0·5 × 0·07 in. † Flaw 0·38 × 0·06 in.

notch by curves with radii much greater than the average size of the unit of crystalline structure of the metal. For ease of experimental investigation the effect of a scratch or group of scratches may be studied with advantage in a transparent body. If, for example, a scratch is made in the edge of such a plate under tension or bending stress, the stress concentration produced can be observed, and if the mean tension is say one-third or even less than that of the yield-point of the material it is usual to observe signs of overstress at the scratch, while, if the load is alternating, these indications gradually penetrate farther and farther into the material, apparently along planes inclined at 45 deg. to the line of pull in ductile bodies, that is, along the planes of maximum shear stress.

In a group of scratches sufficiently close to affect one another, the combined result is, naturally, still more noticeable, and the failure of a material under a comparatively moderate mean stress, due to surface scratches is not difficult to understand, especially if the loading is of an alternating kind.

The form of the scratch produced is all important, and a comparative estimate of various types can be easily obtained without the complication of microscopic examination by examining notches on the large scale under conditions in which the influence of boundaries, other than those of the notches themselves, are practically unimportant. If this is done it can be shown,* for example, that a scratch producing a semi-circular groove in the material may raise the stress to about double the average stress, while a groove with straight sides at 45 deg. and a radius at the apex of one-eighth of the depth gives an increase of rather less than five times the mean stress, according to the recent measurements of one of my research students, Dr. Paul Heymans.

Increased sharpness of curvature at the bottom of the notch produces still greater local stress, and this latter may easily cause a fine crack to develop and produce failure owing to its rapid extension into the material caused by the abnormal concentration of stress at the extremities far transcending the ability of the material to bear, even if it approached the tenacity which it seems possible it might have from calculations of intrinsic pressure and, in the absence of cracks, flaws and cavities.

* E. G. Coker, "Photo-Elastic Measurements of the Stress Distribution in Tension Members Used in the Testing of Materials," Min. Proc. Inst.C.E. 1921.

DAMAGE TO TYRES AND RAILS CAUSED BY BRAKES OR SLIPPING WHEELS.

By CHRISTER PETER SANDBERG, C.B.E., M.Inst.C.E.

INVESTIGATION into the mutual action between steel or iron brake shoes and the wheels or rails to which they are applied, indicates that under the intense pressures which are now frequently employed for the rapid deceleration of vehicles, the rubbing surfaces are subjected to actions of a somewhat complicated and peculiar nature. The energy absorbed by the brakes is immediately converted into heat, and this heat must be dissipated chiefly by conduction into the mass of metal behind the slipping surfaces. The rate of such heat conduction is limited, and, if the rate at which heat is generated is greatly in excess of this limit, a very marked local rise of temperature will take place. If the surface temperature attained does not exceed the lower limit of the critical range of the material, then no marked changes beyond those due to mechanical deformation and abrasion will be produced; if, however, the temperature of this range is exceeded, then in any ferrous material containing over, say, 0·3 per cent. carbon, very definite structural changes will occur. If the thickness of the heated layer is small in comparison with the whole mass, then directly the heating effect ceases the surface will be very rapidly cooled by conduction, and if the temperature has exceeded that of the critical range the metal will be left in the hard or martensitic state. Examination of the surfaces of brake shoes, wheels and rails has shown that the formation of such a hardened surface is by no means unusual. If the surface hardening were the only result of severe brake action, it would not be particularly harmful, and would indeed help the surface better to resist further wear by rolling abrasion; unfortunately, however, the

FIG. 4. WEARING FACE OF CHILLED IRON BRAKE SHOE. × 5.

hardening is accompanied by other phenomena of a much more serious nature.

Both direct experiments of specimens from materials which have been subjected to service conditions, indicate that in addition to the thermal formation of a hardened skin the following action may also take place: Sliding of one surface over the other proceeds to a point at which both surfaces have become so heated that they are soft and plastic and tend to seize together at numerous points of contact. Whilst so united the surface layers are dragged bodily forward forming an overlap in advance of each area of adhesion and a tear behind it. The adhesion is only momentary, and the surfaces are quickly dragged apart, and recommence to slip over one another until sufficient rise of temperature and softening have occurred to cause another seizing. This alternating action of seize and slip probably occurs many times per second during the application of the brakes, and gives rise to the jarring or squeaking noises which accompany such applications, the period of the sound vibration evidently bearing a relation to the periods of slip and seize of the brakes. The result is to produce a series of surface tears or cracks upon both brake block and the wheel or rail, the cracks running in a direction at right angles to that of the motion, and forming at regularly-spaced intervals, evidently bearing a relation to the periods of seize and slip.

FIG. 5. TREAD OF RAILWAY RAIL A BROKEN IN THE TRACK. FULL SIZE.

FIG. 6. TREAD OF RAILWAY RAIL B BROKEN IN THE TRACK. FULL SIZE.

Numerous examples of such cracks have been found upon wheel tyres, and even in a more marked degree upon tram-rails acted upon by powerful (magnetic) track brakes. Corresponding cracks are also found upon brake blocks, which vary in composition between chilled cast-iron and mild steel. In the cases examined, the spacing and also the depth of the cracks appeared to be greater upon the brake blocks than upon the tyres or rails, *e.g.*, on tyres and tramway rails the cracks are usually from $\frac{1}{32}$ in. to $\frac{1}{16}$ in. apart; upon the chilled cast-iron brake block used on wheels about $\frac{1}{16}$ in. apart; and on soft mild steel brake shoes used on the tramway rails from $\frac{1}{4}$ in. to $1\frac{1}{2}$ in. apart.

Photographs illustrating the surface appearance of such cracks are shown in Figs. 1 to 4.* Fig. 3 shows cracks on the surface of a tram-wheel tyre. Fig. 4 cracks upon the chilled cast-iron brake block used upon wheels such as shown in Fig. 3. Fig. 1 cracks on the surface of a tramway rail subjected to the action of magnetic track brakes. Fig. 2 cracks on the surface of the brake shoe of a magnetic track brake.

With such structures as a steel tyre, which is firmly shrunk upon a rigid wheel centre, or a tramway rail which is supported throughout the whole of its length, there would appear to be no tendency for the surface cracks caused by brake action to spread downwards to any appreciable depth.

Sections cut at right angles to the surface and to the line of the cracks, show that in such cases the maximum depth is only a fraction of a millimetre. The existence of such cracks upon a tyre or a tramway rail is thus without any measurable effect upon the liability to fracture, and the chief point to be considered is that the cracks are evidence of very excessive wear, since, owing to the manner in which they are formed, portions of both surfaces must at the same time be wiped bodily away. This wear is additional to that due to ordinary rolling abrasion common to electric traction; and where, owing to special traffic operating conditions, abnormal use of track brakes takes place, the total wear may be two or three times greater than is the case under normal running.

Brakes are not used directly upon railway rails, and hence over the greater part of the track damage caused by brake action does not enter into consideration. The results of wheel braking may, nevertheless, be directly responsible for damage to rails when the brakes are applied with such violence as to lock the wheel and to transfer the sliding motion from between brake block and tyre to between tyre and rail. In addition to this possibility we have the fact that locomotive driving wheels frequently slip when starting, and especially so if the start has to be made upon an up grade. We have obtained direct evidence that from one, or from both, of these causes (*i.e.*, skidding or slipping) surface damage may be done to a sound rail which may lead to its ultimate failure in the road. The surface cracking of a railway rail is essentially more serious than that of a tyre or a tramway rail since it is only supported at intervals along its length, and is bent to an appreciable extent each time it is loaded. Under such conditions there is a definite tendency for a surface crack gradually to spread downwards, and to continue doing so until the section is sufficiently weakened to fail suddenly and completely under a normal working load.

Photographs illustrating the failure of two railway rails (A and B) due to surface damage by skidding or slipping wheels are shown in Figs. 5 to 8. Figs. 5 (rail A) and 6 (rail B) are taken looking directly down upon the tread, and in each case it will be seen that the texture on the upper edge is quite different from that on the lower, the former having a glazed appearance instead of a dull leathery one. Across the glazed surface can be seen a series of cracks running transversely across the rail tread. In Fig. 5 the cracks are somewhat unevenly spaced, but average about $\frac{1}{4}$ in. apart; while in Fig. 6 the spacing is less (about $\frac{1}{8}$ in.), and is remarkably regular. Fig. 7 shows a cross-section of rail A. The cracks do not, of course, appear in this section, but it clearly shows the

FIG. 7. CROSS-SECTION OF HEAD OF RAIL A. FULL SIZE.

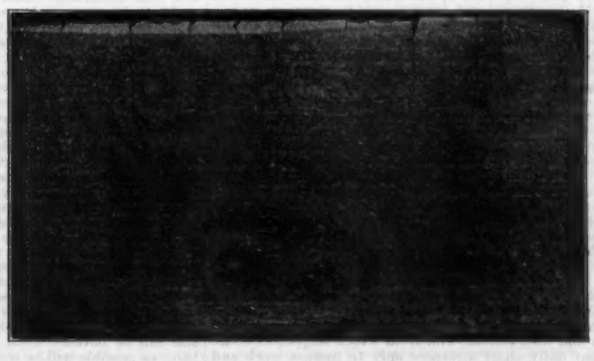


FIG. 8. LONGITUDINAL VERTICAL SECTION OF RAIL B. × 5.

* These photographs were shown as lantern slides at the meeting.

layer of hardened steel occurring on the same edge as the cracks. The depth of this layer was in places as much as $\frac{1}{8}$ in., and traces of it could be found up to the centre of the rail tread. Fig. 8 shows a longitudinal section from rail B, taken about $\frac{1}{2}$ in. from the edge. The hardened surface layer and the cracks are clearly visible. The majority of the cracks do not extend beyond the hardened layer, but two of those appearing have extended to distances of 0·2 in. and 0·15 in. respectively below the surface. Detailed investigation of both these cases has left no doubt that the failures were due to the gradual development of these cracks, which were formed in the first instance by skidding or slipping wheels.

Particulars as to the service, &c., of these two rails, which were kindly given us by the engineers of the railways from which they were taken, are given in the table on page 82. It should be especially emphasised that in both cases the rails, as judged by mechanical tests and macroscopical and microscopical examination, were originally of satisfactory character, and should under normal circumstances have remained unbroken until they were worn out. Chemical analysis from rail B indicates that it was made from an "under-blown" cast, but the resulting composition cannot in any way be held responsible for its failure.

It may be noted that references to rail damage caused by skidding or slipping wheels have been made in several recent American publications* under the title of "Snow-burns," skidding or slipping being more frequent when snow is lying upon the rails. In general it would appear that these investigations have ascribed the formation of the cracks to the failure of the hard and brittle martensitic skin under subsequent wheel loads. According, however, to the views outlined above, our own investigations point rather to the fact that the cracks are actually formed momentarily in advance of the martensite, and that their subsequent formation is doubtful or at least of minor importance.

Since occasional slipping or skidding cannot be avoided there is no sovereign remedy against rail failures of this description. The original surface damage is, however, clearly visible upon the rail tread, and could be observed during routine rail inspection. Any rail showing either a hardened surface or the still more important sign of transverse cracks such as have been illustrated above, should, we think, be treated with suspicion and very carefully watched, and the latter cases preferably be removed from the track.

It is probable that the two cases of rail failure given above are typical examples of many others for which no adequate explanation has been found. It would add greatly to the interest of any discussion on this paper if railway engineers would bring forward any cases of failure which might have been caused by similar circumstances.

THE EXISTING PRACTICE OF INSPECTING WORK AND MATERIALS.

By GEORGE HATTON, C.B.E., M.Inst.C.E.

AT the present time it is the almost universal practice in engineering undertakings that they shall be executed under the direction and guidance of a professional engineer, and that the materials employed shall comply with his definite specification. The development of this practice has been a very gradual one, commencing in the first instance with Government Departments, railway undertakings at home and abroad, dock and harbour works, &c., until now it has become the generally-adopted practice in all undertakings of any importance. In the development of this practice it has been the custom of each engineer, as a result of his own particular knowledge and experience, to define the procedure to be followed in carrying out the work under his care, and the quality and properties of the materials to be employed therein.

With the growth of knowledge and experience in the properties of materials, the range of these specifications has been narrowed down and the desirability for more uniformity of practice is exemplified in the formation of the Engineering Standards Committee with its sub-committees for each branch of engineering practice. Nevertheless, it has remained the custom for each engineer to supervise the work and the inspection of his materials by members of his own staff, so that at the present time we have a large army of inspectors of varying ability travelling about the country inspecting and testing in many instances comparatively small quantities of materials, thus incurring large and unnecessary expense which must either fall upon the undertaking or on the professional engineer himself.

The time seems to have arrived when some systematisation of this practice should be devised by the institution of a Central Inspection Bureau, having possibly headquarters in London and branches or offices in the various manufacturing areas throughout the country to which professional engineers could send their specifications and instructions, and from which inspectors could be sent daily short distances only to inspect work and material, the Bureau to report thereon to their clients. The work of inspection would thus be carried out on more systematic and efficient lines, and a great saving of time and expense would be effected. A uniform scale of charges, subject to revision as a result of experience, could be instituted, and the direction and control of the Bureau could be placed in the hands of a small committee of the Institution of Civil Engineers. The aim of the Bureau should be to give the most efficient service to the engineering profession at the least possible cost compatible with efficiency, and beyond the maintenance of a small financial reserve there should be no attempt to make a profit.

As exemplifying the practicability of such a scheme, no better illustration can be cited than the admirable inspection department of Lloyd's Register of Shipping, which deals with the building of ships and all the materials employed therein under one organisation. In the United States of America the work of inspection has been largely systematised under one general organisation.

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* *E.g.*, Interstate Commerce Commission.—Report of the Chief of the Bureau of Safety covering Investigation of an Accident which occurred on the Baltimore and Ohio Railroad, at Glenwood, W. Va., on December 11, 1919.

SECTION V.—SHIPBUILDING.

THE DESIGN OF FABRICATED SHIPS FROM THE LABOUR-SAVING POINT OF VIEW.

By MAURICE EDWARD DENNY, C.B.E., B.Sc., Assoc.M.Inst.C.E.

THE lexicons define the word "fabricate" as to "form or put together by art and labour." In the modern sense as applied to ships the word has come to mean "the assemblage, to form a ship, of parts previously worked up in an establishment other than the shipyard." The designer is not concerned with the reasons which have induced the shipbuilder to adopt fabrication. These may arise (as during the war) from national emergency, or may be founded on considerations of rapid construction, or low ultimate cost. Normally a shipyard receives plates and sections directly as they come from the steel mill. It is now proposed to interpolate between the rolling mill and the shipbuilder a new agent, whose duty it is to punch, drill, shear, plane, scarph or roll the material in certain predetermined fashions.

It is assumed that the designer has received his instructions so far as the speed, deadweight, draught and general type of vessel desired are concerned, and has worked out dimensions and developed generally a design which will satisfy the requirements. As the power required in the engine-room will not be great, he will have specified that single-screw machinery shall be fitted, thereby avoiding the complication of bossing. Bearing in mind that his design must primarily be effective from the labour-saving point of view, the designer will concentrate his energies on the following: (1) The omission of non-essentials and the reduction of the number of parts to a minimum; (2) the duplication of parts to facilitate repetition processes; (3) the substitution of machine for hand operations; (4) the elimination of members or processes requiring highly skilled operators, and the substitution therefor of simpler pieces or processes.

For many years the trend of ship design has been in the direction of omission of, and reduction in, the number of parts. Something, however, can still be done. The designer may decide, for instance, to dispense entirely with keelsons in the double bottom except forward and in way of machinery, the stem bar might be deleted, and the beam knees in the neighbourhood of a bulkhead might be omitted.

Reduction in the number of parts suggests wide-spaced frames, but in this connection the designers will not push matters to extremes. Few frames connote large and heavy sections; similarly, an attempt to reduce riveting and caulking by the employment of long wide plates may defeat its own ends. If the shipyard is not accustomed to handle very heavy pieces, and if the appliances at the manufacturers' shops are not also suitable for the purpose, no good end will be served by departing widely from standard practice. By means of duplication of parts much labour may be saved. Template work will then be possible to a great extent, facilitating setting-off and reducing the possibility of errors. The multiple punch is no longer a novelty for ship work, and full advantage should be taken of its power of rapid and economical production. In the structural shops multiple drills can be utilised, and if one plate can be used as a jig for a batch of others the saving effected is obvious.

The ordinary ship form produces elements having frequently pronounced curvature in two directions, which is inimical to simple and repetitive work. A modified form, however, can be adopted which will much simplify procedure without unduly increasing resistance or sacrificing seaworthy qualities. Such, for instance, is a straight frame form. Should such be adopted, the following may be expected to occur: (*a*) No frame bending will be necessary, the requisite straightening being done cold by machine; (*b*) furnaced plates will be very much reduced in number; (*c*) the number of plates which require to be rolled will be much reduced.

It may be objected that frame bars must be heated in order to be bevelled, and efforts may be made to design transverse members which do not require bevelling. This can be done, but it is believed that the difficulties introduced thereby do not compensate for the complications introduced. Side frames of even considerable size can be bevelled cold. Naturally as much midship body as possible will be made parallel when no bevelling will be required within that section, but considerations of hull resistance impose pretty definite limits to this procedure.

The deck beams may be made without camber. The loss in draught, and therefore deadweight, for any given depth of ship, is not great. Proposals to abolish sheer also, should, however, be most carefully examined. The loss in draught on account of complete absence of sheer is serious, and the seaworthy qualities of the ship are seriously impaired. In fact, it might be necessary to add a forecastle which had not otherwise been considered essential.

In an indirect manner some labour may be saved by reducing the number of different sections used in the hull construction. It is possible to do all that is necessary by the employment of eight or nine different sections. The steel works are thereby enabled to plan for large rolling programmes, and there should be no check in the steady flow of material from the mill to the manufacturers. This restriction will probably mean that the hull weight will be greater than would otherwise be the case, and in other directions also saving of labour will probably be accompanied by a slight reduction in deadweight. The designer may decide, for instance, to dispense with the joggling of beams and frames, and to use slips instead, which will add somewhat to the weight of the finished structure. The owner, however, might be prepared to accept this situation, and will do so with equanimity if the cost per ton deadweight of his ship is lower than could otherwise be attained.

The shell plating of the ordinary ship form includes a certain number of plates which are difficult to fashion, notably in the region of the stem, stern frame and counter. The omission of the stem has already been suggested, and if special care is given to the design of the stern frame and after end generally, much of this highly-skilled work may be avoided. To effect this, castings may require to be used instead of forgings, and the change-over may seem extravagant from the monetary point of view. Here, as elsewhere, enthusiasm must not be allowed to outrun discretion, but judicious compromise may effect a substantial saving in labour.

In conclusion, it should be added that the designer must seek the advice and closest co-operation of those members of the staff who are responsible for the actual erection of the ship in the yard. Shipbuilding is an art and not a science, encrusted with tradition, and hedged about with labour agreements. To assume that these can be quickly altered or even modified is only to court disaster.

ECONOMY OF LABOUR ON SHIPBUILDING AS EFFECTED BY FABRICATED SHIPS; THE MANUFACTURING PROBLEM AND HOW IT WAS SOLVED.

By JOHN CHARLES TELFORD, O.B.E., Assoc.M.Inst.C.E.

IN dealing with this subject I propose to give the members a brief outline of the methods used by the bridge builders who were engaged on the production of fabricated parts for the "N" and "N 1" type of vessel. The dimensions of these vessels were 411 ft. 6 in. between perpendiculars by 55 ft. 5½ in. beam and 38 ft. 1½ in. depth to top of shelter deck. The vessel was designed to carry 10,000 tons burden, and was propelled by geared turbines.

The work was under the control of the Admiralty, and was placed with various bridge firms throughout the country. It was the writer's duty to co-ordinate the work of the various firms and to introduce methods which would insure the interchangeability of the several pieces making up the construction of the vessel in question.

The calling in of the bridge builders was done by the Government with a view to increasing the production of ships owing to the loss of vessels occasioned by the war, the idea being that these fabricated ships should be assembled by unskilled labour in shipyards specially laid down to deal with the work. I venture to think that some of the methods introduced to produce the fabricated parts were different from the established shipyard practice, and I think I shall be able to demonstrate the economy of manufacture if similar means were adopted in the shipyards for dealing with ship construction on mass production lines.

The premier requirements to make fabricated ship construction a success are several vessels all alike, standardised so as to make the detail reproduce itself many times over, also: (*a*) Careful work in the drawing office and template loft; (*b*) accurate workmanship in the ships; (*c*) close inspection; (*d*) the provision of ample means for checking the several parts with jigs and templates as the work proceeds.

In the case of the "N" and "N 1" type of vessel, the manufacturing problems were complicated by the fact that there were about 55 firms manufacturing the several parts at one time, each firm doing the work best suited to their machines.

After the ship designers had finished their drawings these were passed over to a group of constructional draughtsmen, whose duty it was to prepare the shop drawings. The fabrication of the midship portion of the vessel presented no difficulties as it was of rectangular construction and was handled quite easily on ordinary bridge yard lines. After the arrival of the drawing of the shell plating in the workshop, the first operation was to set out the holes on an actual plate, and afterwards this setting out was carefully checked over by two independent men, the holes being centre-popped and ringed round with white lead so as to clearly indicate where drilling was required. The marked plate was then put on top of a batch of five plates of similar size and made secure by clamps, and then placed under high-speed drilling machines of either the gantry or radial type. These plates, after drilling, now formed templates to enable six machines to be kept drilling corresponding plates. The average output from high-speed drilling machines is about 500 to 600 penetrations per shift of 8 hours, and as the plates are drilled through batches of five plates plus the template, this means 2,500 to 3,000 holes per shift, and the drill can be handled by a boy or unskilled man. During the war girls were employed, and in a few cases the output was above the figure given above.

After the plates were drilled they were taken apart and the arris was cleaned off. Holes to be countersunk were attended to by the usual type of countersinking machine. The plates then passed along the shops to the plate-edge planing machines, the table of each machine being provided with pegs on to which the holes

in the plate to be planed fitted. The travelling tool-box of the planing machines was fitted with a jig to prevent the tool cutting beyond a fixed distance from the centre of the holes. By this means it will be seen that no marking-off whatever was employed in the production of the shell plates beyond the preparation of the first template plate, thus effecting an economy in platers' labour. The edges and one end only of the outer strakes of shell plates were planed for caulking. The inner strakes were only planed on one end.

After the plates had been planed, drilled, &c., they were then marked with the letters "N" or "N 1," indicating the type of vessel, also the piece mark of the plate, together with a code letter indicating the firm who had manufactured the piece. These marks were stencilled on with white lead paint and also steel stamped on to the surface of the plate. The plate mark was further steel stamped on both ends of the plate; this was done so as to facilitate the picking out of plates from the stacks as they lay in the stockyard of the shipbuilder.

The above remarks apply equally to the manufacture of deck plates, tank top plates, and other plating work about the vessel. In connection with the fabrication of the floor girders, &c., which were sent to the shipyards riveted up as complete units, the angles were prepared by multiple punch, the webs being in most cases drilled in batches as described for shell plates. The manholes in plates and floor girders were made by cutting out with oxy-acetylene blowpipe, or punched out, whichever method suited the manufacturer best. Special precautions were taken so that the open holes left in any riveted work were accurate for coupling up to other makers' work. Steel jigs were employed to hold the angles or gusset plate while being riveted so as to prevent any draw or displacement of the open holes.

The side frames were of double angles, 9 in. by 4 in. by ½ in., riveted Z-bar fashion, and these angles were ended up on ending machines to dead lengths, being batched in 30 to 35 angles each time. The bars were then either drilled or multiple punched, the end cleats and gussets being held in steel frames while they were being riveted on. As a further check a travelling system of interchange of gauges was employed to ensure all makers working alike. The fore and aft ends of the vessel presented a great many difficulties, but within the limits of this Note I can only touch on one or two of the principal cases.

The shipbuilders each produced in their shipyards a sample vessel of the "N" and "N 1" type, and it was from their setting out in the loft and templates that the dimensions were obtained to enable drawings to be prepared so as to convey proper information to the bridge builders for the construction of the fore and aft ends of the vessel. The frames throughout were all made a series of straight lines, which greatly assisted the bridge builders, as there was nothing to trouble about except the bevel of the bar. The rolling-mills supplied three sections of 9 in. by 4 in. by ½-in. angles. The first was the usual 90-deg. right-angle section, the other two were rolled to a splay of 100 deg. and 110 deg. respectively. The section was provided with a special heel to assist the metal when the section was opened out. By means of a special bevelling machine the angle was opened out cold to the correct varying angle throughout the length of the bar.

The information in connection with the special-shaped shell plates was given to the bridge builders in the form of an actual plate from the shipyard, which the bridge builders were asked to reproduce. This original template plate had actually been fitted to the vessel. The curvatures at various points along its length were known from the setting out in the ship's loft, so that after the plate was taken down from the ship's side it would be flattened out and used as a template for batch drilling, the right and left-hand plates being simply made by countersinking on the one side for the right-hand and the other side for the opposite hand. The contour was made to set boards, and except for eight plates the whole of the shell was fabricated in the bridge yards ready for going into its place on the ship. I have reason to believe that the work came together satisfactorily.

SHIPS' PROPELLERS: NOTE ON RESULTS OF EXPERIMENTAL RESEARCH REGARDING "CAVITATION" AS AFFECTING PROPULSIVE EFFICIENCY.

By EDWIN RICHARD MUMFORD.

THIS note is confined to consideration of the causes and effects of "cavitation," as indicated by results of special experimental investigation. Models of ships, propellers, as usually tried in an experimental tank, give reliable results for comparison with those of non-cavitating ships' propellers, by the application of Froude's well-known "Law of Comparison"; but when the conditions are such that the ship's propeller cavitates, the model screw does not cavitate at corresponding speeds and slips, because the atmospheric pressure on the surface of the water is the same for model as for ship, instead of being in the ratio of the dimensions; and as the degree of cavitation depends upon pressure difference per unit area, which is greater for ship than model (being in the ratio of the respective similar dimensions) the "Law of Comparison" is not applicable for direct comparison without correction.

It appears that there are four conceivable kinds of "cavitation," two of which cause the formation of persistent cavities in the water to the extent of reducing appreciably the mass of water acted upon in relation to the nominal slip of a propeller, and thus necessitates a relatively increased speed of slip, with consequent loss of propulsive efficiency in order to develop the desired thrust ($T = MV$). The other two kinds of "cavitation" are almost co-existent when they occur, and are probably the cause of the excessive and rapid erosion of the material of propeller blades that sometimes takes place.

The four kinds or conditions of "cavitation" may be described as follows:—

(*a*) When the relation of the size and immersion of the propeller to the power and thrust transmitted is such as to cause air to be drawn down from the surface—the cavities in such case being air filled.

(*b*) When the reduction of pressure immediately forward of the propeller is sufficient to cause air or other gases absorbed or diffused in the water to be freed and to concentrate in the vicinity of the propeller.

(*c*) When the reduction of pressure at the propeller is sufficient to cause momentary conversion of the adjacent water into vapour.

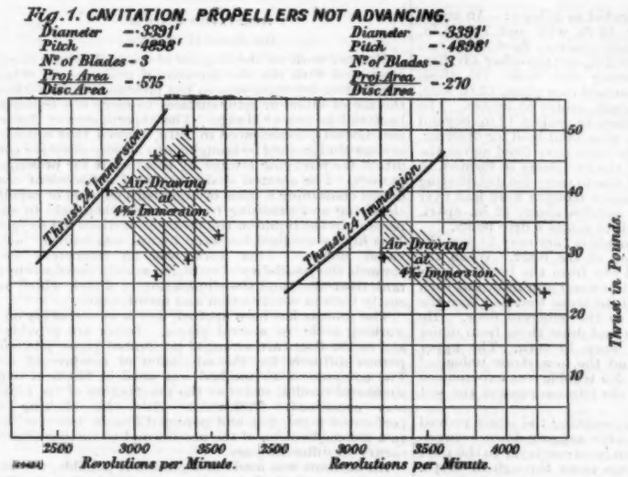
(*d*) When the reduction of pressure is sufficient to cause a nearly perfect vacuum.

In practice, condition (*a*) is a very common cause of loss of propulsive efficiency—probably much more common than is generally known—because, when it does happen it is not easily observed, owing to the turbulence of the water surface. Two model propellers, each about 4 in. in diameter and of 6 in. nominal pitch, the one having about twice the blade area of the other (projected area ratios 0·27 and 0·575 respectively) were driven at such revolutions per minute in undisturbed water while not advancing, as to draw air from the surface, the immersion of the centre of the horizontal shaft in each case being 4·15 in. It was found that the smaller blades drew air from the surface when the nominal slip was 26·1 ft. per second, and the thrust per square inch of projected area 10·53 lb., while the larger blades drew air from the surface when the nominal slip was 22·4 ft. per second, and the thrust per square inch of projected area was 5·14 lb. (See Fig. 1.) The immediate drop in thrust when air-drawing commenced, amounted to 35 per cent. and 40 per cent. respectively, and the character of the thrust curve seems to be similar to that found by Admiral D. W. Taylor in the Washington Tank, and published by him in Figs. 220 to 224 in his book on "The Speed and Power of Ships." Another non-advancing model propeller, 3 in. in diameter, about 4·3 in. nominal pitch, and projected area ratio of 0·575 drew air in a vortex from the surface when the centre of its horizontal shaft was immersed 2 ft., the nominal slip was 27·7 ft. per second, and the pressure per square inch of projected area was 7·4 lb.

Condition (*b*) frequently occurs with vessels of the fast cross-Channel type, torpedo-boat destroyers, and other vessels fitted with screw propellers impressing a high absolute speed of slip on the water acted upon. This phenomenon was made plainly visible by means of a stroboscope; air bubbles were seen to form at different parts of a model propeller of 3 in. diameter driven at high absolute slips up to about 40 ft. per second nominal. The bubbles so formed were observed to persist as such in a spiral train in the race of the propeller.

In order to investigate this condition further, experiments were made with model screws with centres immersed 2 ft. on a horizontal shaft in undisturbed water, and driven up to and beyond all known speeds of slip of ship's propeller, and at different speeds of advance. No air was drawn from the surface during these experiments. It was intended to measure the shaft horse-power and thrust in terms of the nominal slip of the driving face of screws of different pitch ratios, but a difficulty occurred in connection with the measurement of the load friction of the apparatus, so that, for the present, only the curves of thrust are available. The results show a gradual reduction of relative thrust commencing at various nominal speeds of slip, and various pressures per unit area of projected surface, depending upon the ratios of pitch to diameter, of projected area to disc, and speed of advance. The commencement of the thrust breakdown occurs at higher nominal slip with increase of pitch ratio and increase of speed of advance. The maximum nominal speed of slip so far obtained at the commencement of breakdown of thrust is 34 ft. per second associated with a pressure per square inch of projected area of 8¼ lb., which is the minimum so far obtained. The minimum nominal speed of slip obtained at the breakdown point is 17 ft. per second associated with a pressure of 12·95 lb. per square inch of projected area and a speed of advance of 600 ft. per minute. The maximum pressure per square inch of projected area carried by one of the screws up to the breakdown point was 15·7 lb. at a speed of advance of 600 ft. per minute. The curve of thrust beyond the breakdown point in all cases showed the falling-off to be gradual, and not in the least degree of the same character as when air is being drawn from the surface. Though the rate of falling-off in propulsive efficiency remains to be explored, it may be said that the one fairly reliable test shows that a 25 per cent. increase of slip beyond the breakdown point involves a loss of about 20 per cent. of propulsive efficiency, and the loss increases with further increase of slip. (See Fig. 2.)

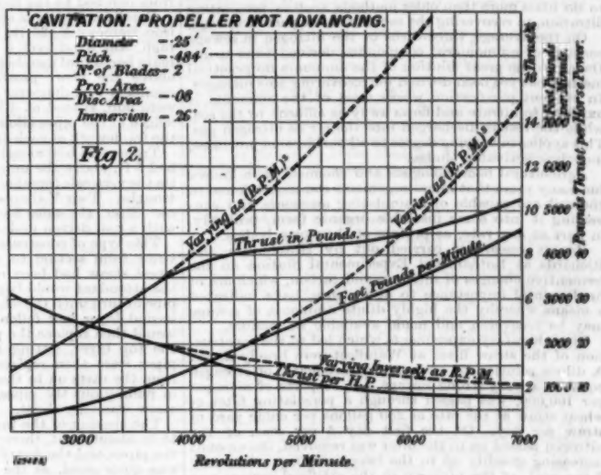
Fig. 1. CAVITATION. PROPELLERS NOT ADVANCING.



Observations of undisturbed sea water subjected to reduction of atmospheric pressure under the glass bell of an air pump showed that bubbles began to form when the pressure was reduced by about 6 lb. per square inch, and that they increased in magnitude with further reduction of pressure. This pressure difference at a propeller would give a speed of flow of water towards it of about 30 ft. per second. In the turbulent wake of a ship the bubbles will probably be formed at a lower average speed of flow. The pressure of water vapour at 60 deg. F. is only ½ lb. per square inch. Assuming a propeller to be immersed 6 ft. in water at such temperature, and impressing such a speed on the water as to create a region of absolute pressure of only ½ lb. per square inch, then the speed of flow of water towards that region due to the combined head of atmosphere and water, less the ½ lb. per square inch, will be about 50 ft. per second, which is so much in excess of the average speed of slip of any ship's propeller that it appears probable that air bubbles extracted from the water by pressure difference, and thus reducing "M," are the usual cause of breakdown of thrust and efficiency of propellers of high-speed ships when not drawing air from the surface.

Conditions (*c*) and (*d*) cannot exist with any known nominal slip obtained by a ship's propeller if the speed of rotation be uniform, and the propeller advancing into undisturbed water. It is, however, conceivable and probable that minute cavities of extremely low internal pressure are created momentarily when impressing a high speed of slip in a turbulent wake. The alternating pressures during each revolution due to a varying speed of wake may set up vibration of the propeller blades which may further intensify the pressure differences. The minute cavities of low internal pressures thus created probably would not affect propulsive efficiency

Fig. 2.



to an appreciable extent because they could not (like the air bubbles) persist as such, but would collapse almost as soon as created; the blows on the material of the propeller blades, caused by the collapse of such cavities, appear to furnish the only reasonable explanation of the serious erosion that sometimes occurs (see paper by Sir Charles Parsons and Mr. Stanley S. Cook, in vol. lxi of Trans. Inst. N.A.).

It may be of interest to record that in order to make the cavitation tests with small models of 3 in. to 4 in. diameter, the full power of an electro-motor capable of giving 6 s.h.p. was used.

Much remains to be investigated as to the effect of various factors—size, design, immersion and speed of advance—in relation to "cavitation" as affecting propulsive efficiency, but it is hoped that this note will prove adequate to evoke a good discussion of the subject.

SECTION VI.—WATERWORKS, SEWERAGE AND GASWORKS.

STRAW FILTERS FOR SEWAGE PURIFICATION.

By ERIC HANNAFORD RICHARDS, B.Sc., and MICHAEL GEORGE WEEKES, M.Inst.C.E.

IT is universally recognised that the systems of sewage disposal in general use among civilised communities are very wasteful from the agricultural point of view. Only a minute fraction of the fertilising value in water-borne excrement is returned to the soil, and even this small portion is generally confined to insoluble matter or sludge, of low manurial value. The latest process of sewage treatment by activation promises to improve the quality of sewage sludge very considerably, provided that it can be dried economically, but this process seems to do little more than older methods, such as percolating filtration, in recovering the most valuable part of sewage.

On the average, three-fifths of the nitrogen in sewage consists of ammoniacal compounds derived from urine. Owing to the great dilution of the ammonia no practical method has yet been devised for recovering this nitrogen. In efficient purification works most of the ammonia is oxidised to nitrate and flows away as effluent to the sea, while the rest is discharged into the air as nitrogen gas. This applies in varying degree to all purification processes, including activated sludge.

Agricultural bacteriologists and chemists have known for many years that micro-organisms commonly found in the soil are capable of assimilating ammonia and converting it into some insoluble organic form, probably, in part at any rate, as protein of their own bodies.

Recent researches carried out by Hutchinson and Richards at Rothamsted Experimental Station on the fermentive changes of nitrogen and carbon, which are of fundamental importance to agriculture, have indicated a means whereby the highly dilute ammonia of sewage may be recovered and made available as manure.

The laboratory experiments which led to the construction of the straw filter at Wainfleet were briefly these: A dilute solution of ammonium carbonate, of strength equal to a very strong sewage, *i.e.*, 10 parts of nitrogen per 100,000, was passed through a percolating filter of wheat straw at the rate of 250 gallons per cubic yard of straw per day. On the first day 5 per cent. of the nitrogen passed on to the filter was removed, the amount increasing steadily up to the twentieth day, when only 1 per cent. of the nitrogen in the artificial sewage was found in the effluent, the remaining 99 per cent. remaining in the filter. The filter was then mature and continued to remove practically all the nitrogen fed to it until the saturation point was reached.

In the case of wheat straw the filter continued to remove nitrogen until 7 parts had been fixed per 1,000 parts of dry straw. On dismantling the filter the straw was found to have retained 86 per cent. of the nitrogen contained in the original ammonia solution. Twenty per cent. of the dry matter in the straw had disappeared in the process of fixation, so that the nitrogen in the final dry matter had been raised to 1·33 per cent. The effluent was brown coloured but non-putrefactive. It contained too much carbonaceous matter in solution to pass the Sewage Commission's test for dissolved oxygen absorption. When the straw filter effluent had run through an ordinary clinker percolating filter, an effluent was obtained that would pass both the standard tests, but was still very brown in colour. The experiment was then repeated with actual sewage from the Harpenden Works. The results were the same as in the first experiment.

LABORATORY STRAW FILTER AND AMMONIUM CARBONATE.

Nitrogen Balance.

	Grammes.		Grammes.
Nitrogen added as $(NH_4)_2CO_3$ ...	1·400	Nitrogen in effluent	0·121
Nitrogen in straw at start ...	0·759	Nitrogen in straw at end ...	1·965
		Nitrogen lost (3·4 per cent.) ...	0·073
	2·159		2·159

Amount of added nitrogen fixed 86 per cent.

LABORATORY STRAW FILTER AND SEWAGE.

Nitrogen Balance.

	Grammes.		Grammes.
Nitrogen as NH_3 in sewage ...	1·532	Nitrogen in effluent	0·149
Nitrogen in straw at start ...	0·877	Nitrogen in straw at end... ...	1·976
		Nitrogen lost (11·8 per cent.) ...	0·284
	2·409		2·409

Amount of added nitrogen fixed 72 per cent.

When the straw has become saturated with nitrogen it can be removed from the filter, and if stored in heaps will continue to ferment with great improvement in its physical state regarded as a substitute for farmyard manure.

At this stage of the experiments (May, 1919) Richards and Hutchinson chanced to meet Mr. M. G. Weekes, then Chief Engineer to the Board of Agriculture, who was faced with the problem of providing some method of sewage disposal for a hutted camp of 300 navvies to be engaged on the Board's land reclamation scheme on the north-west shore of the Wash. Only urine, cookhouse and ablution shed water would need treatment, but the concentration of the sewage liquor would probably be excessive, and liquors of this nature do not yield readily to treatment on percolating filters.

As the experiments described above had just been completed, the possibilities of a straw filter were discussed, and ultimately a scheme on these lines was put into operation. The original experiments had made it clear that clean straw was not active in removing nitrogen, but that it gradually became more so as sewage was passed through it, the best results being obtained after 20 days of treatment. For this reason it was decided that the filter must be in sections and that the straw must be passed from section to section so that the sewage always met the newest straw first and finished by passing through the most active section. It was also decided that three sections would be sufficient, as this would give one section fully active and another nearly so, when clean straw had to be added. The first intention was to construct three shallow beds arranged in steps, but when the details came to be got out it was found that the head required to give three systems of distribution was too great to make the scheme practicable, and, further, that there would be considerable labour in forking the straw from one bed to the next.

Finally a filter was constructed as follows:—An angle-iron framework, 20 ft. long, 10 ft. wide and 7 ft. 6 in. high, was fixed over a sloping concrete floor, with two main horizontal members, one 2 ft. and the other 4 ft. 6 in. above the floor, passing along each side. On these members 1 in. diameter galvanised iron pipes, 12 ft. long, were laid, spaced at 4 in. apart, centre to centre. The length of the pipes allowed them to project 12 in. beyond the framework at each end to give hand-hold for drawing.

Transverse horizontal angle-irons were fixed across the bed 3 ft. above the upper of the two floors so formed, to tie the verticals together and also to carry the distributing troughs. Two V-shaped wooden troughs were laid over the filter, the sides having notches about 12 in. apart, with a nail driven under each to act as a drip point.

This type of construction made it very easy to pass the straw from section to section of the filter. When the ripest straw had been raked out from the bottom layer the attendant would begin at one end and draw out each pipe in turn until the whole of the straw that had been the second layer had fallen on to the concrete floor. He would then replace the pipes and draw those from under the top layer, letting that down in turn. The upper pipes were then replaced and the new straw unloaded from the carts on to them. No trouble was experienced in pulling out the pipes, as the friction against the wet straw was very slight.

The spacing of the pipes supporting the straw proved to be about right, there was little sagging down between the pipes, and the distribution from one layer to the next was quite good, as the sewage came through in drops. The distribution from the troughs was very faulty at first, until the attendant got used to keeping them adjusted and cleaning the notches, but later it was sufficiently good for this layer, which is not really operative, but merely being prepared to become so.

The pump that fed the filter could not be worked at a slower rate than about 17 gallons per minute. This would not have given too quick a rate of application had both units of the filter been in use, but with only 50 gallons storage capacity in the tank first installed it was too fast for one filter. Moreover, it took some time to persuade the pump driver that the rate of pumping really mattered, so that at first he ran his pump as fast as possible unless he was watched, and the actual rate of application of the sewage was as high as 450 gallons per cubic yard per day, instead of the 60–80 gallons required. Under these conditions it is not surprising that the actual removal of nitrogen by the filter was very small. But even then the effluent was free from smell, and neither at this nor at any subsequent time was there any nuisance from the filter itself or from the ditch receiving the effluent, nor did flies collect round the filter. The rate of flow to the straw was gradually reduced to 96 gallons per cubic yard per day by restricting the tank outlet pipes, with a corresponding improvement in the nitrogen recovery. The best purification, as measured by five days' dissolved oxygen test, was 80 per cent. Negative purification was generally shown by four hours permanganate.

When a new tank of 960 gallons capacity was installed the improvement in nitrogen recovery was very marked. The best figure recorded was 65 per cent. of the nitrogen in the sewage. On incubation for 5 days the effluent was invariably putrid. From such a strong liquor, ten times as strong as normal sewage, it is probably impossible to produce a non-putrescible effluent by straw filtration alone.

WAINFLEET STRAW FILTER.

Average Analyses of Samples taken after Installation of Larger Overhead Tank, July–September, 1920.

	Parts per 100,000. Sewage.	Effluent.
Ammoniacal nitrogen	18·92	10·19
Oxygen absorbed in four hours from permanganate	31·88	20·82
Dissolved oxygen taken up in five days	80·4	14·9
Chlorine	31·0	39·3

	Dry matter. Per cent.
Total nitrogen in raw straw	0·50
" in straw removed from filter...	1·62
" after storage for six months ...	2·06

In order to recover all the nitrogen possible about 2 lbs. of dry straw per man per day is required. During the year's working at Wainfleet the amount of straw used was considerably less. For a period of 35 days 2,800 lbs. of dry straw passed through the filter and 49 lbs. of nitrogen was pumped on to the straw in the sewage. The weight of straw shown by laboratory experiments as necessary to recover this amount of nitrogen is 5,000 lbs. Even if the rate of flow had been low enough to allow proper biological action, only about half the nitrogen could have been recovered. The straw removed was, in fact, overloaded with nitrogen all through the experiment. The resulting manure, after storage in a heap alongside the filter, was of excellent quality, containing 2·06 per cent. of nitrogen, and was in good condition for applying to the soil. This manure has no smell whatsoever.

The practical application of this process is so far limited to such sewage works as have access to straw in quantity, and where a demand exists for farmyard or stable manure which cannot be met at present. There are, however, many places in this country where these conditions now exist, while the supplies of stable manure are rapidly diminishing.

Straw is by no means the only substance suitable for the process, and further research may show how the less digestible carbohydrates in sawdust and other vegetable waste products may be made available.

ACTIVATED SLUDGE.

By JOHN HAWORTH.

RECENT work on the disposal of sewage has been chiefly concerned with the development of processes to obtain purification by organisms in the presence of air, without the use of filters or solid surfaces to carry the necessary bacterial humus or sludge. The experiments of Ardern and Lockett, commenced in 1912, showed that ordinary sewage sludge could be brought into a more effective condition for purifying sewage by aerating it for prolonged periods. The aerated sludge assumed a flocculent condition containing a mass of organisms capable of rapidly clarifying and oxidising fresh sewage when held in suspension in the liquid in the presence of dissolved oxygen. This highly oxidised bacterial humus was named "activated sludge." This work was an important step towards the possibility of reducing sewage purification to tank treatment, and the elimination of filters, which are costly both in construction and maintenance.

The process has been applied, and is in operation on a working scale, in several places. Tanks are provided, and in the floors are arranged perforated pipes, jets, and porous diffusers for the admission of compressed air. The compressed air method was tried in Sheffield with successful results, so far as the purification of the liquid was concerned. Difficulties with the choking of perforated pipes, jets and porous diffusers, however, led to a reconsideration of the process and to further experiments on different lines.

An attempt was made to separate, if possible, the two functions performed by the compressed air, namely: (1) The supply of dissolved oxygen for the maintenance of the biological life, and (2) the purely mechanical action of agitating the sludge in the liquid. It was found later that by suitably agitating sewage sludge in tanks open to the atmosphere, results exactly similar to those obtained by the use of compressed and diffused air could be produced. Experiments have been in continuous operation for two to three years in tanks divided by partitions, so as to form a continuous channel, and provided with agitators of varying types to circulate the liquid at such a velocity as to prevent deposition of the sludge or humus and at the same time to present constantly changing liquid surfaces to the atmosphere. These experiments were operated on the "fill and draw" system.

In November, 1920, a large tank, 200 ft. by 76 ft., divided into eighteen sections by thin division walls, so arranged as to form in gridiron fashion a continuous channel 3,544 ft. long, was put into operation on the "continuous flow" system. Circulation and agitation is obtained by means of 18 paddle wheels arranged on two shafts across the centre of the tank, each shaft being driven by a 20 brake horse-power motor. The liquid is thus continuously circulated round and round the tank. Sewage is admitted into the flowing stream at a point remote from the outlet, which is a weir formed in the wall running the whole length of the return end of the tank. The effluent liquid is settled in tanks of the Dortmund type, and such bacterial sludge as is needed is pumped back to the circulating tank. The results up to the present are highly promising from all points of view. Volumes of strong sewage up to 500,000 to 600,000 gallons per day are satisfactorily dealt with.

The important questions now to be settled are engineering ones, namely, the most efficient means: (1) Of producing rapid changes of liquid surface, and (2) of holding the humus in suspension.

Among the conclusions arrived at from the Sheffield experiments the following may be of interest:—

(1) That in any satisfactory plant the small orifices must be eliminated. It is difficult to imagine how small jets or diffusers can have permanence in operation when unwashed air, such as is found in large towns, is continuously passed through them. It is noteworthy that in the large installations proposed in America air-washing plant is to be provided.

(2) The Sheffield experiments appear to indicate that air in small bubbles is not essential. It may be pointed

out that in the case of percolating filters and contact beds all the oxygen necessary to produce efficient oxidation is taken up by solution from the atmosphere.

(3) It is open to discussion whether, when air bubbles are blown into water, the bulk of the solution of oxygen does not occur at the disturbed and changing surface of the liquid, and not by direct solution from the bubbles, in which case the use of compressed air becomes chiefly a mechanical means of producing agitation or circulation.

(4) It is, therefore, a question whether the use of compressed air, as a mechanical agitator, is as economical as the employment of a direct mechanical appliance such as a paddle or screw. The act of holding the sludge in suspension in the liquid depends on velocity of flow, and as this is dependent on head to overcome the resistances in the tanks, the question is largely one of efficient and economical means of producing head. Experience points to the paddle or screw having the advantage in this respect.

The writer has been unable to find examples of circulating or agitating large volumes of liquid under conditions such as are required by this process. The available engineering information on this matter is also very limited and opens a field for useful investigation. Observations in the case of the Sheffield tank rather indicate that, when working within the limits of good running efficiency, the horse-power required varies approximately as the square of the velocity of flow, but this appears to have been contested by some engineers.

(5) The rate of purification is dependent on: (1) The strength of the sewage or the amount of putrescible matter to be oxidised; (2) the definite period of time required by the organisms to complete their work; (3) the rate at which the water will take up dissolved oxygen. Tanks should, therefore, be designed of ample capacity to suit the sewage to be dealt with under its strongest conditions.

(6) The de-watering and disposal of the sludge or humus from the process is perhaps the most difficult and urgent problem to be solved, owing to the gelatinous or colloidal condition of the sludge and its large water content. Where ample land or ash filters are available, the sludge can be spread in thin layers, and readily cakes and dries. Experiments in de-watering the material by pressing or centrifuging have not proved satisfactory. The writer has found that by spreading the wet sludge on paper-maker's gauze and applying a slight vacuum to the under surface a great reduction in the water content can be obtained very rapidly. This line of attack may offer a practicable solution of the difficulty. Sludges containing 98 per cent. to 99 per cent. of water are reduced to about 75 per cent. almost immediately. The thin cakes thus produced readily dry in air, and in a few days can be pulverised. If artificial heat could be utilised economically, rapid drying might be accomplished.

Two small experimental machines have been constructed on this principle. One has a travelling gauze band passing over a vacuum box, as in the papermaking machine, the other consists of a gauze-covered revolving segmental vacuum drum dipping slightly into the wet sludge, which picks up a film of sludge in touching the liquid, and this is dried as the segments leave the liquid. The cake can be removed by allowing a flat surface to touch it, to which it readily adheres. A steel roller is used for this purpose, the cake being removed from the roller by a fixed scraper. The method is worthy of the attention of engineers.

Until the sludge problem is satisfactorily dealt with the difficulties of sewage engineers in this respect will be increased rather than diminished, except where ample land for drainage and drying is available. The fact that the sludge would have a value as a fertiliser, if in a condition to be manipulated, renders it possible to expend more on its disposal than is the case with ordinary sewage sludge.

DE-WATERING SLUDGE.

By JOHN DUNCAN WATSON, M.Inst.C.E.

THE water content of sludge removed from a frequently cleaned sedimentation tank is not less than 92 per cent. to 94 per cent., the water content of activated sludge about 99 per cent., and that of humus sludge, which is also activated with nitrate forming bacteria, about 98 per cent. to 99 per cent. Notwithstanding the numerous claims that have been made to utilize this undesirable substance, only two methods are able to de-water effectually, and neither is patented. One is evaporation of moisture by heat, a method, I fear, too costly to become economically practicable, and the other is biological decomposition plus air-drying, a method nearer than any other to Nature's way of rendering nocuous substances innocuous.

It is the latter process as it is conducted at Birmingham that this note attempts to describe. Want of space forbids more than a mere reference to the benefits of the septic tank which is the foundation of the process. An attempt was made in Birmingham twenty years ago to septicise sludge *per se*, but it failed. Better results were obtained at Hampton by Dr. Travis, who inaugurated the hydrolytic tank, but it was the improvement effected on that tank by Dr. Imhoff, engineer to the Emscher District Drainage Board, that showed the way to what is now done on so large a scale at Birmingham.

Imhoff tanks do not provide adequately for occasional rushes of inhibiting liquors like tar, acid, and producer-gas waste, nor do they admit of sufficient latitude in working. Variation of flow during wet weather on a large plant is a point of the first magnitude which the German plan failed to provide for adequately.

The Birmingham plan meets these drawbacks by discarding the German attempt to combine functions of septic and sedimentation processes in one composite tank, providing instead separate tanks to perform each function separately. The sedimentation tanks are of the old-fashioned rectangular pattern, encouraging precipitation of solids by regulating the velocity of flow. These tanks, which yield in the aggregate 300,000 tons per annum, are freed from sludge once a week, when it is pumped into tanks specially reserved for sludge digestion. The ability of the digestion tanks to absorb great volumes of crude sludge into a mass which is obviously in an active condition of fermentation without even temporarily retarding the septic process, is a distinct advance on the Imhoff plan, and it provides an elasticity in working the installation which is of inestimable value.

The following method of working has obtained since 1912 without intermission. Sludge is transferred daily from the sedimentation tank whose turn it is to be emptied by the main set of pumps, into the selected digestion tanks, generally six in number. Simultaneously some of the ripest available sludge is pumped from another digestion tank by a smaller pump into the same delivery main in the proportion of 1 to 4, thus inoculating at the earliest possible moment the fresh sludge with organisms which promote putrefaction. In cold weather it is found advisable by injecting steam to raise the temperature as nearly as possible to that most favourable to fermentation. In moderately warm weather steam is not needed, and in summer neither steam nor inoculation is essential. The biological factor governing the digestive process must necessarily be paramount, and it is only by careful observation of the conditions which produced the right balance of organisms that success can be achieved. When this balance is upset objectionable stench ensues, and sludge subsides to the bottom of the tank, instead of being buoyed up with gas.

Dr. Imhoff concluded that his fermentation chambers should be large enough to contain from four months' to six months' storage, and the author has found that the minimum requirement for Birmingham sludge during the past six years was a tank capacity of 165,000 cub. yards, or 28,000,000 gallons, which is equal to a storage of four months, but he agrees with Imhoff that it should be more.

It has been proved that sludge dries more readily when the digestive process has been carried to exhaustion, and this should be done invariably before it is pumped to the drying area. Provision of ample tankage upon which so much depends is therefore essential. Experience has shown that properly designed tanks cannot be too urgently insisted upon, as variations in the composition of the sewage are constant, whether they are due to change of temperature, sudden inrushes of acid waste, or even to strikes with their consequent effect on the volume of trades waste in relation to domestic sewage; well designed tanks of ample size contribute to minimise trouble.

An important factor in pumping the rotted sludge, or residuum of the fermentation process, to the drying beds is the buoying up of the particles of sludge by gas globules. Apparently these gas bubbles act like so many ball bearings between particles of solid matter as they are propelled along the main, reducing the friction to a minimum. The samples exhibited show the sludge when thoroughly ripe floating on the liquid, and if it can be got to the drying beds in this condition, the liquid is readily absorbed and led to the underlying drains, exposing the solid matter to the air. The time required for drying varies with the weather. Imhoff claimed that the sludge would dry in a few days; it has never done so at Birmingham, where a month and generally several months are necessary. If exposed too long it may even become so dry that eye-protectors will have to be provided for the workmen engaged in throwing the dry sludge into tip wagons.

During the 1912 coal strike, and again during the present strike, this sludge has been used to eke out the supply of slack, and, generally speaking, it has been found that 1 lb. of sludge could raise 1 lb. of steam. Dr. Davidson found that it gave a calorific value of 4,120 B.Th.U., and Mr. Silvester found that a sample dried at 212 deg. F. gave 4,893 B.Th.U.

This process of sludge de-watering is put forward as a complete process in itself, as complete as the Imhoff tank process, but without any suggestion, in this case, that the effluent from the sedimentation tank is fit to be discharged into a stream. It effectively converts an exceedingly offensive colloidal mass into a dry substance, which may be kept indoors for years without giving off more odour than garden soil.

The de-watering of activated sludge after it has served its purpose in a purifying plant remains an unsolved problem, notwithstanding the many attempts which have been made to solve it both in England and in America. It would be impossible to enumerate all the attempts which have been made, but amongst others which stand out prominently there may be mentioned centrifuging chemically treated as well as untreated sludge, plate pressing, while trials have been made quite recently in Sheffield of the effect of spreading it over gauze and afterwards submitting it to a slight vacuum.

The author is hopeful that success will come, but so far success cannot be recorded. His own experience of de-watering humus, which in its fresh state is similar to activated sludge, is not encouraging. The humus which breaks away from the percolating filter has a water content of 98 per cent. to 99 per cent., and is so complete an emulsification that a filter constructed on the principle of a waterworks filter failed to pass the moisture. Turning it into deep trenches, lagooning it in shallow square plots of gravelly soil, spreading it over grass land, centrifuging it, all failed. It was then decided to pump it back to the silt tanks, through which sewage has to pass on its way to the bacteria beds, but here again failure had to be recorded, as the result was an extraordinary growth of thread-like algæ which choked the distributors. There is no more difficult problem on a sewage works than that of de-watering humus.

SECTION VII.—ELECTRICITY WORKS AND POWER TRANSMISSION.

LOW-VOLTAGE OVERHEAD DISTRIBUTION.

By BURKEWOOD WELBOURN.

General.—The distribution of electrical energy by bare overhead conductors has not been so favourably considered in the United Kingdom as in Canada, the United States of America, Italy, France, Spain, &c., and it was scarcely used in this country until after 1890, when it began to be fostered by Mr. Gerald Balfour, the then President of the Board of Trade, at the instigation of Mr. A. P. Trotter. Since then overhead distribution has made slow progress and has been wholly or partially used in a good many rural townships, &c., two of the oldest and most important schemes being those of Ebbw Vale and Ystradgynlais in South Wales. It is neither desirable nor possible to cover all the points concerning an overhead system within the limits imposed on these notes, and the author proposes to deal chiefly with some important features which need discussion.

Standardisation.—The B.E.S.A. has recently issued a specification for creosoted wood poles, and has in hand the preparation of specifications for telegraph and telephone line materials. Much of the work is in an advanced state and several of them should be ready for issue this year. The specifications which deal with insulators and pole fittings will be particularly useful for light power work, while the elaborate specification for different types of tubular light steel poles may be helpful in some directions. The B.E.S.A. also has in preparation specifications for copper and aluminium conductors and steel strand, but their completion is dependent on the results of extensive tests which are being made at the National Physical Laboratory for the B.E.A.I.R.A.

Regulations.—Overhead lines are required to comply with "Regulations prescribed by the Board of Trade under Section IV of the Electric Lighting Act, 1888." These regulations are now administered by the Electricity Commissioners under the Ministry of Transport in accordance with the Electricity Supply Act, 1919, and it is understood that they are now under revision with the assistance of an *ad hoc* committee appointed by the I.E.E. It should be noted that the existing regulations prescribe factors of safety as follows:—

Line wires	5	at least.
Wooden poles	10	
Iron and steel structures ...	6	

taking the maximum possible wind pressure at 25 lb. (altered from 30 lb.) per square foot, while no addition need then be made for a possible accumulation of snow. No temperature is mentioned but it is presumed that 22 deg. F. is intended. These factors of safety are highly controversial—they are seldom observed, and it is generally hoped that they will be replaced by some more logical rules this year which will obtain ready acceptance.

Points on which discussion would be helpful are:—

Voltage.—Whether, in the interests of standardisation of lamps, motors, &c., as well as of voltage regulation, it is possible to arrange for new work to be carried out at a declared voltage of, say, 240 volts to the neutral. Regard should be paid to the question of transforming down to some lower voltage at each house and, if so, whether a higher voltage to the neutral than 240 is permissible on the street wires.

Conductors.—Whether these should be stranded only or whether solid wires are permissible under any circumstances having regard to the fact that the conductors may be of (*a*) copper or (*b*) aluminium, or even of (*c*) steel or iron. Attention might also be paid to the use of weatherproof wires and their limitations.

Services.—Whether these should be of bare wire or of insulated cable.

Height of Wires.—Whether the present minimum of 22 ft. from the ground might be reduced for certain classes of roads.

Poles.—Experiences with different types of poles: (*a*) Creosoted wood; (*b*) tubular and lattice steel; (*c*) reinforced concrete.

With this question is wrapped up the large question of the possibility of making use of houses to carry brackets for the supporting of conductors without danger to the public or to the residents or to workmen employed on the houses.

Protection of the Public.—Whether the present methods of guarding required by the Electricity Commissioners and the General Post Office are sufficient or too onerous, and in what directions they might be simplified or made less costly.

Lighting Protection.—Whether anyone has discovered any entirely effectual way of preventing lightning getting on to the internal house-wiring.

Earthing.—For lines which give a supply to consumers at pressures above 250 volts, the regulations require that a continuous earth wire should be provided, that all metal work on each pole should be connected to it, and that it should be definitely "earthed" at every fifth pole. Nothing is said about earthing at pressures below 250 volts, and, owing to the doubt which exists on the point, it is hoped that the Electricity Commissioners will make an early pronouncement on the subject. The author is decidedly of opinion that the fittings on each pole should not be "earthed" by a single wire coiled into a flat spiral beneath the lower end of the pole. There are various objections to it, the chief one being that the surrounding ground may not in all cases provide an efficient "earth." Discussion on this subject is very desirable.

Cost.—The question of distribution by overhead wires *versus* underground cables is a controversial one, and cases may sometimes be settled by first-cost considera-

tions, but, fortunately, æsthetic and maintenance conditions are sometimes given their full value—especially in garden city schemes. In one such scheme the total first cost of the overhead distribution, including 108 public lighting fittings, has been 6,800*l.*, whereas the estimate for a high-class scheme using cables throughout was only some 20 per cent. higher. Allowing for the longer life and lower maintenance charges on cables, it is very doubtful whether there was any real saving by using overhead wires in this case. Exact costs obtained from other schemes would be very useful.

Conclusion.—The author has always held the view that overhead distribution has a special field of its own in the development stage of the electric supply industry in the United Kingdom—particularly in rural areas and in works and colliery distribution. The standard of work and appearance, as well as of continuity of supply, are much higher here than in many other countries, and the author believes that ultimately the distribution in all our towns, garden cities and large villages will be done by underground cables. The basis for this belief partly lies in the growing practice of the General Post Office in replacing overhead wires by cables even in country villages.

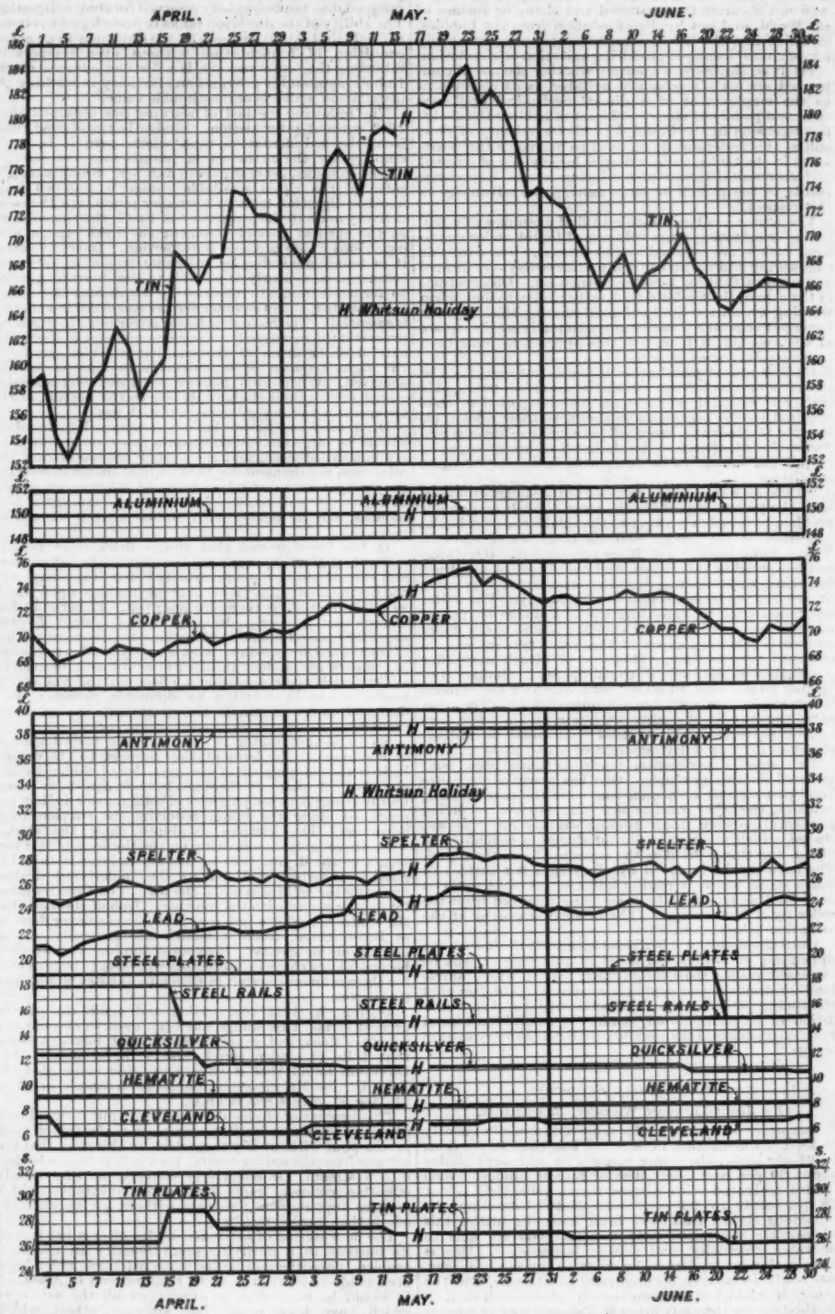
SHIPBUILDING AND SHIP REPAIRING IN THE BAHAMAS.—According to a statement by the Bahamas Development Board, there is an opening in those West Indian Island Colonies for the establishment of a shipbuilding and repairing yard in Nassau. The present slipways are capable of accommodating small vessels only, but with the development of the port, a dry dock or slipway to accommodate for repairs, vessels of 1,000 tons or over, will become a pressing need, especially as new facilities for reaching Nassau via Halifax are already available by means of the Canadian Government Merchant Marine Steamers. It is impossible under the present conditions to effect repairs to machinery at Nassau and such repairs are sent abroad to be executed at necessarily greater cost than if done locally.

REINFORCING A BRIDGE CORRODED BY LOCOMOTIVE GASES.—Broadway, in Cleveland, crosses the tracks of the New York, Chicago and St. Louis Railway (Nickel Plate) on a steel-deck plate-girder bridge built in 1888, according to the *Engineering News Record*. On account of extensive corrosion of the floor system of this structure in recent years, especially over two shunting tracks, the bridge was marked for early replacement. Corrosion had attacked especially the top flanges of the 38 in. plate-girder floor beams, which were found to be greatly reduced in area, and some holes had developed even in the web below the top flanges. The corrosion was almost as bad in the sidewalk brackets outside the girders as in the floor beams between the girders, although the girders themselves showed little injury. Financial conditions, however, delayed the renewal of the bridge, and it became necessary to reinforce the structure in order to maintain it in service. New stringers had been put in some years ago, and as the main girders, 66 in. deep, were not seriously affected, the floor beams and sidewalk brackets were the principal items to be dealt with, and this only in the three panels over the drill tracks. It was decided that the floor beams were not much weakened but that they could be left in place and counted upon for partial duty if supplementary floor beams were put in to take part of the load and be available for full service in case of failure of the old beams. This scheme was carried out, using 20-in. I-beams taken out of another structure. An I-beam was placed transversely midway between the old floor beams, being riveted to the main girders after bringing it up to bearing against the stringers. The cantilevered sidewalk brackets were dealt with in the same way. Additional stiffeners and kneebraces were placed on the main girders at the connections of the new floor beams. According to George H. Tinker, bridge engineer of the Nickel Plate, who carried out this reinforcement, two cast-iron sewer and water pipes suspended 5 to 10 ft. below the bridge floor do not appear to have been injured by the locomotive gases. The iron hanger rods supporting these pipes are attacked, however, and must be replaced from time to time.

THE HARDNESS OF ELECTROLYTIC IRON.—In the year 1906, Dr. H. C. Boynton, of Harvard College, communicated to the Iron and Steel Institute an account of experiments on the "Hardness of Constituents of Iron and Steel," interesting also on account of the method by which he determined the hardness. He made use of the microsclerometer of Professor T. A. Jaggar, also of Harvard, in which a fine diamond point is rotated at very high speed and the depth of the hole drilled is measured. Experimenting on pure electrolytic iron, ferrite, Boynton found that the etching of the original or remelted specimens made no difference in the hardness, the relative hardness figures being 505 and 460, but that quenching from high temperatures doubled the hardness, quenching at 850 deg. C. (β iron) raising the hardness to 998, and quenching from 1,300 deg. C. to 982. In *Stahl und Eisen* of May 12 last, Drs. V. Bauer and W. Schneider, of the Technical High School at Breslau, describe experiments, made by a different method, which do not show this marked influence of quenching. They took cubes of electrolytic iron, of 10 mm. edge, normalised by heating to 950 deg. C. for half an hour, and quenched them from eight different temperatures ranging from 650 deg. up to 1,250 deg. C. Determining the hardness by the Brinell method, they found no influence of the quenching temperature at all, all the hardness values lying between 57 and 59·3. They do not question the accuracy of Boynton's results, however, but point out that the Brinell hardness is not the hardness of Boynton. The former marks the resistance which the material opposes to penetration of a harder substance into it, whilst the Jaggar method measures the resistance opposed by the smallest particles to the rotating diamond. Brinell hardness and capability of being machined do not go together; austenitic manganese steels are soft and yet difficult to machine, whilst the Boynton hardness would indicate the relative ease with which the material can be machined. Bauer and Schneider also made tensile strength tests, on strips of 16 mm. by 2·5 mm. cross-section, 120 mm. long, without finding any noteworthy differences caused by quenching, and other tests with turned rods, reheated in a vacuum, were equally concordant. But Bauer and Schneider did not extend their examination to various steels as Boynton had done.

DIAGRAMS OF THREE MONTHS FLUCTUATIONS IN PRICES OF METALS.

(Specially Compiled from Official Reports of London Metal Markets.)



NOTE.—In the diagrams the figures plotted for tin and copper are the official closing cash quotations of the London Metal Exchange for fine "foreign" and "standard" metal respectively. The prices shown for lead are for English metal, whilst those for spelter are for American metal. Middlesbrough prices are plotted for steel plates and rails, and also for hematite and Cleveland pig-iron. The prices given, in the case of steel plates are for ship, bridge and tank qualities, and those for steel rails are for heavy sections. The pig-iron prices are for the East Coast hematite and Cleveland iron, both of No. 1 quality and for home consumption. The price of tin-plates is per box of I.C. cokes free on board at Welsh ports, but in all other cases the prices are per ton. Each vertical line in the diagram represents a market-day, and the horizontal lines represent 1*l.* each, except in the case of the diagram relating to tin-plates, where they represent 1*s.* each.